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SOVIET INSTRUMENTATION AND
CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis, permitting readers to appraise for themselves the scope, status, and importance of the Soviet work.

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IMPORTANT PROBLEMS IN DEVELOPING STATE STANDARDIZATION AND NORMALIZATION

Successful fulfillment of the Seven-Year Plan of the USSR national economy requires a further extension of standardization and normalization. Improvements in this respect are very important for speeding up technical progress, introducing group mechanization and production automation, developing specialization and cooperation with the object of a further expansion of industrial production, improvement in the quality of commodities, and reduction of the cost of production.

In fulfilling the tasks set us by the June Plenum of the CPSU Central Committee, we must expand state standardization of the principal types of industrial and agricultural production in order to prepare for the transition to production according to State Standards in the coming 2-3 years.

State standards should provide typical sizes for machines, equipment, and instruments, and specify the quality not only of current commodities and materials, but also of those planned for production, incorporating in their specifications the latest achievements of Soviet and foreign technology.

These important tasks involve a large amount of scientific research and experimental design work, the collection of the required data, the production of test samples and series of samples, and the manufacture of new, high-quality machines, equipment, instruments, and commodities.

In order to develop further industrial production and raise specialization and cooperation in industry, it is necessary to radically improve the unification and normalization of similar components, units, and commodities. The unnecessary variations in the types of equipment, units, and components of machines, instruments, and gages and other technological equipment as well as any unnecessary multiplication of sizes and types of commodities must be eliminated.

In the coming two years engineering standards must be developed for all gages, devices, dies, and other technological equipment in general use, and in the next three to four years state standards and engineering specifications for general machine units and components and the principal means of mechanization and automation designed for mass production must be developed.

In order to ensure a technical basis for specialized industrial production according to unified specifications, it has been laid down that general and specialized engineering specifications compiled and approved in the proper manner become binding for establishments and organizations irrespective of their administrative subordination.

For the purpose of coordinating the work and standardizing and normalizing various production groups and ensuring technical uniformity in different branches of national economy, a large group of scientific research institutes and development and design organizations and establishments have been entrusted with the regional supervision of standardization and normalization.

These organizations must work out drafts for state standards and specifications, compile plans for coordinating the work of various plants, scientific research institutes, and development and design organizations engaged in developing specialized specifications for various groups of products, must control the fulfillment of the plans for drafting specifications, conduct scientific research and experimental work in connection with the development and introduction of State Standards and specifications, and must prepare proposals for a timely revision of State Standards and specifications which do not satisfy modern requirements.

It is necessary to strengthen the control over establishments to ensure their conformity to the figures and requirements contained in State standards and specifications with respect to their production. The coordinating

organizations are also empowered to control the introduction and preservation of State standards and specifications at the plants and other organizations. The plant administrations must be made more strictly responsible for allowing production to deviate from the standards, specifications, and technical requirements.

The planning agencies and Councils of National Economy are instructed to specify in their plans the introduction of new types, kinds, and brands of commodities for which State standards and specifications have been drawn up, by the specified time and in quantities which would satisfy the requirements of national economy.

A further development of State standardization and normalization is very important for instrument making and measurement techniques. It is particularly important in this major sphere of activity, which is intimately connected with production automation, to improve standardization and normalization and ensure by their means the introduction of new modern measurement technique, the unification of instrument components and units, and the organization of specializations and cooperation in the instrument and automatic equipment producing industry.

In the first half of November, 1959, the Committee of Standards, Measures, and Measuring Instruments of the Council of Ministers of the USSR approved the standardization plan for 1960.

In the section of this plan entitled "Control and measuring instruments and equipment", which was compiled in conformity with the advanced plan for important work in standardization in 1959-1965, and by taking into consideration a further improvement in the work of State standardization, a number of problems are solved in connection with speeding up technical progress, introducing group mechanization and automation of production, and improving the quality of production.

Considerable attention is paid in the plan to automation of measurements and standardization of instruments and equipment connected with production automation.

Such work includes the development of a standard for "Pneumatic unified group control and regulation system AUS", standards for hydraulic and pneumatic actuating devices for controlling and regulating production, and a standard for pneumatic amplifiers for telemetering and pneumatic instruments and other standards.

An important place is devoted to the work of introducing better means of physicochemical measurements and temperature measurements, modern electrical measuring equipment, instruments for linear measurements, including the development of new standards for automatic and semiautomatic gas analyzers, instruments for measuring hydrogen ion concentrations (pH-meters), thermocouples for measuring molten metals, ac bridges, electrical measurement recording instruments, equipment for measuring tapered and worm gear wheels, universal gages for measuring internal dimensions, etc.

In 1960, standards for radio measuring equipment will be established for the first time, and will cover tube voltmeters, standard signal generators, heterodyne and resonance frequency meters, pulse generators, amplitude modulation factor meters, etc.

In order to raise the quality of instruments and improve their accuracy and reliability, the plan provides the revision of a number of outdated standards, which no longer correspond to the modern requirements of measurement technology.

Considerable attention in the plan is paid to the standardization of components, units, and instruments used in mass production, thus ensuring their specialized production.

Such work includes the standardization of common weighing equipment knife-edge and thrust bearings, suspension shackles for weighbridges, portable dial scales for 50-3000 kg, clock mechanisms for recording instruments, mercury-in-glass electrical contact thermometers, electronic amplifiers for heat-control instruments, magnets for instruments, suspensions and torsion suspensions for electrical measuring instruments, cases for recording instruments, automobile tire pressure gages, and other instruments.

The fulfillment of the standardization plan for 1960 outlined under the section "Control and measuring instruments and equipment" will amount to an appreciable contribution towards introducing modern measurement techniques into our national economy.

Workers in the instrument-making industry are faced with important problems in fulfilling the measures required for a further development of State standardization and normalization and better quality control and measurement instruments inspection, to ensure a successful fulfillment of the Seven-Year Plan for the development of our national economy.

CERTAIN PROBLEMS OF ACCURACY IN AUTOMATIC CHECKING OF DIMENSIONS

M. I. Kochenov

Effect of measurement errors on the sorting of commodities. The ratio of the limiting error Δ_{lim} to the value of the measured dimensions tolerance 2δ does not by itself determine the accuracy of commodity sorting, which is characterized by the relative quantity of commodities correctly assigned to a certain category. The sorting accuracy depends with a given Δ_{lim} to 2δ ratio on the law of commodity distribution. If this law is known, the probability of the measurement errors' effect on the accuracy of commodity sorting can be approximately found as follows.

Let $f_1(x)$ (Fig. 1) be the differential distribution law of the actual sizes of commodities, which are due to be sorted out into groups of good and rejected ones; a and b are the limiting tolerances as shown on the drawing; $b-a = 2\delta$ is the drawing (arbitrary) manufacturing tolerance of the commodities; $f_2(y)$ is the differential law of distribution of measurement errors. If the limiting measurement errors amount to $\pm\Delta_{lim}$, part of the commodities whose actual sizes lie in the regions from c to a and b to k can be mistakenly passed as good, and those with sizes lying in the regions from a to d and e to b can be rejected (false rejection). In order to determine the probability of an erroneous sorting of commodities, let us divide the commodity size distribution curve in the region from c to d into several parts (for instance, 10) with equal bases and divide the curve of the random errors distribution into the same number of parts of the same size. The probability of obtaining the sizes of commodities and errors of measurement in each of the 10 portions is known since their distribution laws are known. Let us denote the probability of obtaining certain sizes of commodities in determined sections by $p_1, p_2, \ldots, p_{10}$ and probabilities of obtaining measurement errors by $q_1, q_2, \ldots, q_{10}$. Taking the probability of measurement errors exceeding in their absolute value Δ_{lim} to be negligibly small, it is possible to assume that a good commodity whose size probability is p_1 can only be rejected by mistake if that size has been measured with an error whose probability is q_1 (with the corresponding sign of the error). The probability of such an event will be p_1q_1. The rejection of a good article whose size probability is p_2 is possible if this size is measured with an error whose probability is q_1 or q_2. The probability of rejection of such a commodity is $p_2q_1 + p_2q_2$.

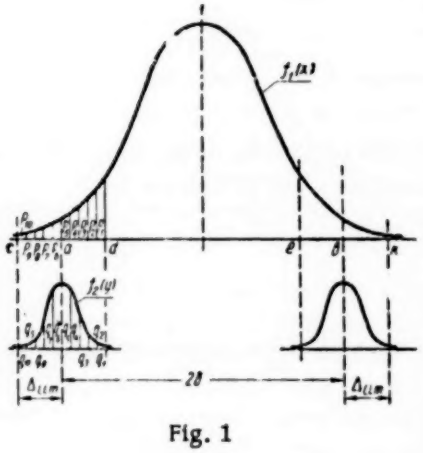


Fig. 1

The probability of rejection of a commodity whose size probality is p_3 amounts to $p_3q_1 + p_3q_2 + p_3q_3$; the probability of rejection of a commodity whose size probability is p_4 amounts to $p_4q_1 + p_4q_2 + p_4q_3 + p_4q_4$; and finally, the rejection probability of a commodity whose size probability is p_5 amounts to $p_5q_1 + p_5q_2 + p_5q_3 + p_5q_4 + p_5q_5$.

The complete probability of rejection of a good commodity will amount to

$$P_1 = q_1(p_1+p_2+p_3+p_4+p_5)+q_2(p_2+p_3+p_4+p_5)+ q_3(p_3+p_4+p_5)+q_4(p_4+p_5)+q_5p_5.$$

The probability of faulty commodities whose size probability is, respectively, p_6, p_7, p_8, p_9, and p_{10} being passed as good, can be determined similarly. The complete probability of such an event amounts to

$$P_2 = q_{10}(p_{10}+p_9+p_8+p_7+p_6)+q_9(p_9+p_8+ p_7+p_6)+q_8(p_8+p_7+p_6)+q_7(p_7+p_6)+ q_6p_6.$$

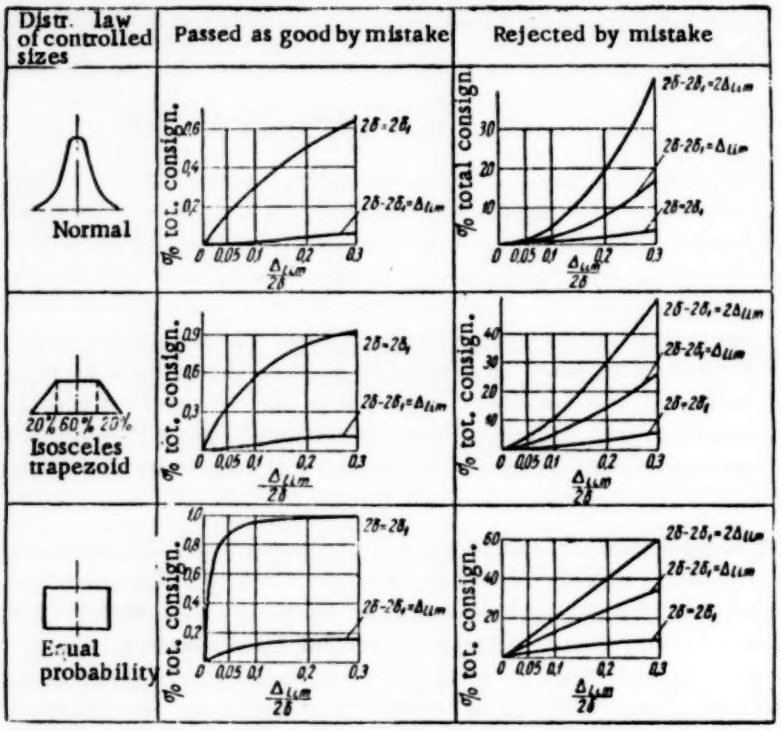


Fig. 2. 2δ) Manufacturing tolerance; $2\delta_1$) acceptance tolerance; Δ_{lim}) limiting error.

The probability of improper sorting of commodities whose sizes lie in the region from l to k (Fig. 1) can be determined similarly.

For symmetrical distribution laws of commodity sizes a complete probability of rejection of good commodities amounts to $2P_1$, and complete probability of faulty commodities being passed as good amounts to $-2P_2$.

The accuracy in determining the values of P_1 and P_2 rises with decreasing intervals into which the two curves are divided.

The solution of the above problem in the general case amounts to the following.

The distribution of the measurement results will follow the law:

$$f_3(z) = \int_{-\infty}^{+\infty} f_1(x) f_2(z-x)\,dx.$$

If a and b are the limiting manufacturing and acceptance tolerances, the probability of the commodity being passed as good (i.e., the probability of the measurement result being between a and b) amounts to:

$$\int_a^b f_3(z)dz.$$

The probability of the commodities being rejected (i.e., the probability of the measurement result lying outside the tolerance region) amounts to:

$$\int_{-\infty}^{a} f_3(z)dz + \int_b^{+\infty} f_3(z)dz.$$

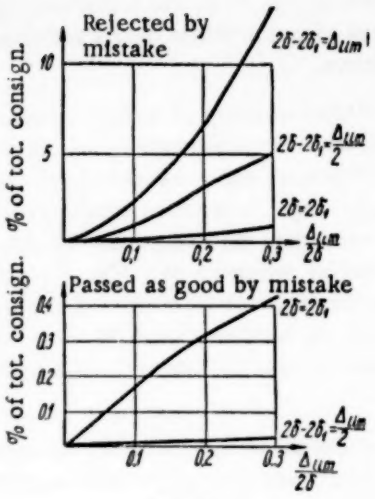


Fig. 3

Both the number of rejected commodities and those passed as good will include a certain portion of wrongly sorted out commodities due to measurement errors.

The distribution of the sizes of commodities passed as good is:

$$f_4(x)=f_1(x)\int_{a-x}^{b-x} f_2(y)dy.$$

Hence, the probability of a wrong sorting out of faulty commodities as good ones amounts to:

$$\int_{-\infty}^{a} f_4(x)dx+\int_{b}^{+\infty} f_4(x)dx.$$

The distribution of the actual sizes of rejected commodities is:

$$f_5(x)=f_1(x)\left[\int_{-\infty}^{a-x} f_2(y)\,dy+\int_{b-x}^{+\infty} f_2(y)dy\right]$$

and hence the probability of wrong rejections of commodities amounts to:

$$\int_{a}^{b} f_5(x)dx.$$

The sorting out of a consignment of commodities by means of an apparatus with a limited accuracy was represented in this form by N. A. Borodachev [1].

With a few exceptions the solution of these problems requires numerical integration.

Figure 2 shows the calculation results of the relative number of wrongly sorted commodities under the following initial conditions.

For the distribution of the actual values of controlled sizes three symmetrical laws were assumed: the equal probability distribution law, the normal distribution law, and isosceles trapezoid distribution law. A normal distribution law was assumed for the measurement errors. It was assumed that in the consignments subjected to the control there were 2% of faulty commodities. The ratios $\Delta_{lim}/2\delta$ of the absolute value of the limiting measurement error ($\Delta_{lim} = 3\sigma$) to the value of the controlled commodity size tolerances were taken as 0.05, 0.1, 0.2, and 0.3. Calculations were made for three different relationships of the manufacturing and the acceptance (decreased) tolerances: 1) when they are equal ($2\delta = 2\delta_1$); 2) when the acceptance tolerance is equal to the manufacturing tolerance decreased at both limits by $\Delta lim/2$, i.e., when $2\delta - 2\delta_1 = \Delta_{lim}$; 3) when the acceptance tolerance is equal to the manufacturing tolerance decreased at both limits by Δlim, i.e., when $2\delta - 2\delta_1 = 2\Delta_{lim}$.

Figure 3 shows the curves representing the effect of the measurement errors on the sorting results of commodities whose parameters are controlled for essentially positive quantities (errors in the shape or eccentricity of the commodities, etc.). Maxwell's law was assumed for the distribution of these commodities and normal law for the distribution of measurement errors. It was also assumed as previously that consignments subjected to control contain 2% of faulty commodities. The relative amount of wrongly sorted commodities was calculated for the same relationships between the manufacturing and acceptance tolerances.

Figure 4 provides the characteristics of the measurement error effect on multirange sorting. When dealing with a large number of sorting groups, it is often possible with sufficient accuracy to assume that the actual sizes of the commodities within the limits of one or one and a half groups are distributed according to an equal probability law, independently of the distribution of sizes of all the remaining commodities. Figure 4 shows the distribution curves of actual commodity sizes within one sorting group and the relative number of commodities which are wrongly included in the group, and are taken for various ratios of the limiting measurement error Δ_{lim} to the sorting group tolerance ξ, ranging from 0.1 to 1. Normal law was assumed for the distribution of measurement errors.

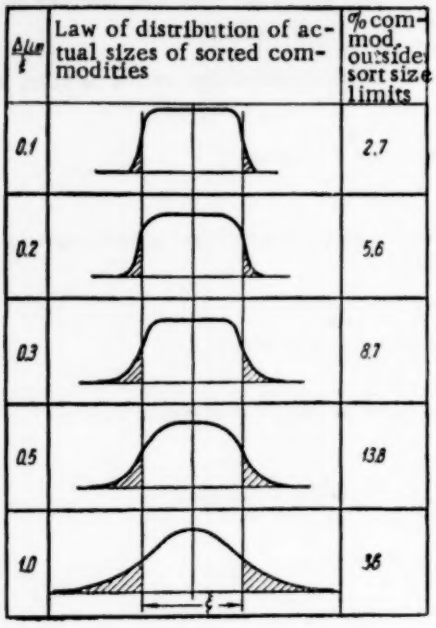


Fig. 4

Thus, the curves shown in Figs. 2, 3, and 4 characterize the effect of errors on sorting of commodities over a sufficiently wide range of initial conditions.

In determining the relative quantity of faulty commodities which are passed as good to errors of measurement, we did not include the faulty commodities sizes which exceed the tolerance limits. These excesses are no larger in practice than the limiting errors of measurement even when the acceptance tolerance $2\delta_1$ is equal to the manufacturing tolerance 2δ. Figure 5 shows a histogram which indicates the distribution of the faulty commodities passed as good under the condition when $2\delta_1 = 2\delta$, when the distribution of the controlled sizes and errors is normal, and when $\Delta_{lim}/2\delta = 0.2$.

It is important to note that all above data refer to commodity sorting by one parameter only. In many cases commodities are automatically controlled for 20-30 parameters and even more, and the total number of incorrectly sorted out commodities increases several times over. When several parameters are checked, the total number M of erroneously rejected or accepted commodities amounts to:

$$M = N\left[1 - \left(1 - \frac{n}{N}\right)^k\right], \qquad (1)$$

where N is the number of commodities in a consignment; n is the number of commodities erroneously assigned to a given category by checking one parameter; k is the number of controlled parameters.

For small values of n/N the expression becomes:

$$M \approx nk \qquad (2)$$

Formulas (1) and (2) hold if N is sufficiently large and if the number of commodities erroneously assigned to a given category is the same for all the controlled parameters. When checking multiparameter commodities, this condition is not fulfilled, since the number of faulty commodities for different parameters is seldom the same. For certain parameters the number of faulty commodities is considerable (attaining 2% and more) and for other parameters it can be very small. When the properties of faulty commodities in a controlled consignment varies and the remaining conditions are unaltered, the number of false rejects also change. Table 1 shows the decrease in "false rejects" when the number of faulty commodities in a controlled consignment is reduced. The number of "false rejects" was calculated for consignments whose actual commodity sizes are distributed according to the normal law and under the condition that $\Delta_{lim}/2\delta = 0.2$.

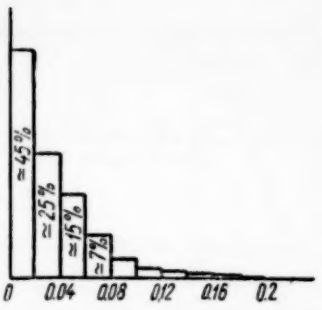
In the general case the number M of erroneously sorted commodities amounts to:

$$M = N - N^k \prod_{i=1}\left(1 - \frac{n_i}{N}\right),$$

where N is the total number of commodities in the consignment; n_i is the number of commodities erroneously sorted out when checked for a single parameter; k is the number of controlled parameters.

In this case all the controlled parameters of a commodity must be considered as independent entities. Thus, if a hole diameter is measured in three directions, each measurement should be considered as a separate parameter.

These propositions regarding the efficiency of acceptance control with respect to the controlled commodity sizes and measurement error distribution laws are basically the same for automatic and nonautomatic control. Experience shows, however, that with the remaining conditions being equal the relative number of erroneously sorted out commodities is higher in automatic than in nonautomatic control. This circumstance is due to the fact that



Values by which the commodity sizes exceed tolerances (in fractions of tolerances).

Fig. 5. Percentage of the total number of faulty commodities passed as good by mistake.

in manual sorting the operator can, in doubtful cases, when the measurement result deviates from the tolerance limit by an amount not exceeding the limiting error of measurement, recheck the commodity more carefully with minimum additional expenditure of time and in many instances arrived at an immediate decision as to what category the commodity actually belongs. Moreover, the operator has the opportunity of rejecting commodities whose sizes, according to the measurement results, exceed the tolerance limits by an amount greater than the limiting error of measurements. Thus, the relative number of commodities which must be rechecked by more precise measurements is smaller in manual than automatic control.

Choice of an optimum accuracy of checking. In modern engineering a distinct tendency to a rising cost of inspection with an increased measurement accuracy is observed. Hence the choice of an optimum inspection accuracy, which is essentially an economic question, must be based on the evalution of the cost of inspection on the one hand and of

TABLE 1

The number of faulty commodities in % \ The difference in the manufacturing and acceptance tolerances	$2\delta - 2\delta_1 = 0$	$2\delta - 2\delta_1 = \Delta_{lim}$	$2\delta - 2\delta_1 = 2\Delta_{lim}$
	The value of "false rejections" in % of the total consignment		
2	1.3	7.5	18
0	0.4	2.5	12

losses caused by sorting errors on the other hand. An accuracy of measurement should be considered optimum when the expenditure on inspection and the loss due to measurement errors are at a minimum.

These considerations and calculations provide the initial data for evaluating the losses due to acceptance inspection errors.

Schematically the solution of this problem can be represented as follows.

Let, for instance, commodities whose actual sizes are distributed according to the normal law be sorted out with measurement errors amounting to 20% of the tolerance value ($\Delta_{lim}/2\delta = 0.2$). Let the number of faulty commodities in the consignments amount to 2%. The operating conditions of the commodities are such that no "seeping through" of faulty ones into those passed as good is permissible. Hence the acceptance tolerance must be reduced as compared with the manufacturing tolerance by the amount of $2\Delta_{lim}$. In this case the number of "false rejects" will amount to ~18% (Fig. 2). The cost of sorting out a consignment will be N rubles and the losses due to the rejection of 18% of good commodities will be P rubles. (These losses can be defined as the cost of rechecking the rejected commodities, or the cost of these commodities if they are not rechecked, but finally scrapped.)

If measuring equipment whose error is 10% of the manufacturing tolerance of the commodities ($\Delta_{lim}/2\delta = 0.1$) is used, the cost of checking a consignment will rise to N_1 rubles. (The cost of inspection increases due to more expensive measuring equipment, the use of labor with a higher skill, and the reduction of inspection productivity.) In this case, however, the amount of false rejections is reduced to 5%, and the losses due to the rejection of good commodities drop to P_1 rubles. The use of more accurate means of measurement will not be advantageous if $N + P > N_1 + P_1$. If the operating conditions are such that a certain amount of "seeping through" of faulty commodities into the consignments of good ones is allowed, the economic advisability of decreasing the acceptance as compared with the manufacturing tolerances should be considered in calculating the optimum accuracy of measurement.

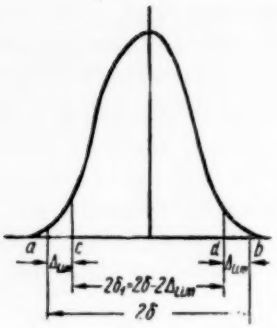


Fig. 6

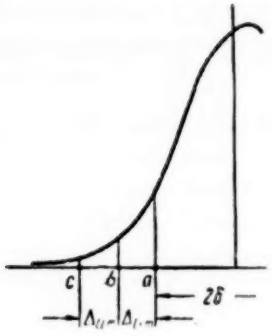


Fig. 7

In the preceding example it was shown that for $\Delta_{lim}/2\delta = 0.2$ and $2\delta - 2\delta_1 = 2\Delta_{lim}$, the number of "false rejects" amounts to ~18% of the total number of commodities in a consignment and that the losses due to the rejection of good commodities amount to P rubles. If for the same conditions the acceptance tolerance of the commodities is reduced as compared with the manufacturing tolerance by half the value of the limiting error of measurement ($2\delta - 2\delta_1 = \Delta_{lim}$), the number of "false rejects" will fall to ~8%, but the commodities passed as good will include ~0.04% of faulty ones. For $2\delta = 2\delta_1$, with the remaining conditions unchanged, the number of false rejects will drop to ~1.3%, but among the good commodities there will now be ~0.5% of faulty ones.

In order to increase the efficiency of automatic checking it is necessary to search, in the first place, for economically feasible methods of raising the accuracy of measurements. It is, however, also necessary to examine other means of raising the efficiency of checking without increasing the accuracy of measurement.

Decreasing the amount of work involved in rechecking the commodities rejected by the automatic equipment. It was pointed out above that in automatic checking of commodity sizes the rejection of a certain (sometimes considerable) portion of the good commodities was inevitable. Therefore all the rejected commodities are usually checked by means of manually operated equipment. The amount of work involved in rechecking the rejected commodities depends to a great extent on the circuit and the construction of the controlling automatic equipment.

In automatic control of multiparameter commodities, all the rejected commodities are either deposited in one common box, or in several boxes, each of which holds commodities checked for one parameter (or several parameters). Such methods of sorting cannot be considered as efficient, especially when the number of "false rejects" is large. If all rejected commodities are deposited in a common box, all their parameters have to be measured in rechecking. The sorting out of commodities according to the type of rejections and depositing them in separate boxes does not greatly reduce the amount of rechecking involved, since the commodities in any of the reject boxes, except the last one (in order of testing) have a number of unchecked parameters. In such a case the parameters for which the commodities were rejected should be rechecked by more accurate means, and the unchecked parameters of the commodities which are passed as good on rechecking their "doubtful" parameter should be checked in an automatic tester or by other means. Let us notice that the use of several boxes for the rejects considerably complicates the construction of the automatic equipment and increases its size.

A reduction in the rechecking work can be attained if it is known for which parameter (or parameters) the commodity has been rejected. In order to obtain this information, devices for appropriate stamping (easily effaceable) of rejected commodities or for supplying special labels for them should be provided.

Automatic rechecking of rejected commodities. Automatically rejected commodities are usually rechecked manually on indicating instruments of greater accuracy and a final decision is then made as to their assignment to a given category.

Let us examine the advisability of rechecking the rejected commodities by passing them several times through the automatic tester. Repeated rechecking of rejected commodities without increasing the accuracy of testing is based on the following proposition: If the limiting error of measurement does not exceed half the tolerance value of the controlled sizes and if the acceptance tolerance is reduced as compared with the manufacturing tolerance by the amount of $2\Delta_{lim}$, a sufficiently extensive rechecking of the rejects will eventually separate the

TABLE 2

Distribution law of the controlled sizes	Ratio of the limiting measurement error Δ_{lim} to tolerance 2δ															
	0.1				0.2				0.3				0.4			
	Number of times the rejected commodities have been rechecked															
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	Number of erroneously rejected commodities after their repeated rechecking by automatic equipment (in % of the total consignment).															
Normal	4.8	3.5	3.0	2.7	17.5	12	9.5	8	41	27	21	18	73	50	40	33
Equal probability	20.5	17	15	14	41	34	30	28	62	49	45	42	82	67	59	54

good commodities from the faulty ones practically completely. In fact, if the manufacturing tolerance amounts to 2δ (Fig. 6) and the acceptance tolerance to $2\delta_1 = 2\delta - 2\Delta_{lim}$, the faulty commodities will not be mixed up with the good ones for any value of $\Delta_{lim} < \delta$. At the first checking practically all the faulty commodities and a part of the good ones lying in ranges from a to c and d to b will be rejected. At each rechecking of the rejected commodities by the automatic equipment all the faulty ones will be rejected and a certain fraction of the incorrectly rejected commodities will be passed as good ones. The relative number of good commodities which are rejected at successive rechecks by the automatic equipment can be calculated by the method used for compiling graphs of Fig. 2. For this purpose it is necessary to determine by means of numerical integration the distribution laws of the actual sizes of commodities which are rejected at the required stage of their rechecking by the automatic equipment. Table 2 shows the effectiveness of rechecking commodities by means of the automatic equipment. The data has been obtained for the following conditions: It was assumed that the controlled sizes were distributed either according to the equal or normal probability laws; the normal distribution law was assumed for the error distribution; and the ratios $\Delta_{lim}/2\delta$ were taken as 0.1, 0.2, 0.3, and 0.4. The acceptance tolerances were made smaller than the manufacturing tolerances by the amount of $2\Delta_{lim}$. The faulty commodities were assumed to amount to 2% of the total of controlled commodities. It will be seen from Table 2 that if the controlled sizes are distributed according to the normal law, a fourfold rechecking of the rejected commodities by the automatic equipment reduces the amount to be checked on manual instruments to about one half; and if the distribution is according to the equal probability law the reduction amounts to 30%.

The efficiency of sorting decreases rapidly with the increasing number of times the commodities are rechecked, however, a three-to fourfold automatic rechecking of the rejected commodities may be advisable under mass production conditions. With the extended use of highly productive electrical methods of checking, the number of rechecks can be considerably increased, thus compensating for the insufficient accuracy of measurements. Let us note that the data quoted above and the general considerations outlined only hold for sorting of large consignments of commodities when there are no substantial systematic measurement errors. The latter condition must be taken into account when automatic testing equipment is designed; the rejected commodities should be checked, if possible, on several test positions instead of one.

Effect of faulty commodities not subject to rechecking. In the cases when the amount of faulty commodities for certain parameters is especially large (for instance, the amount of repairable faults) and the sizes of a considerable portion of the rejected commodities are greater than the tolerance limits by amounts much larger than the error of measurements, it is advisable immediately to separate such commodities without subjecting them to rechecking.

For this purpose a four-contact transducer should be used. Two contacts are used for adjusting the transducer to every tolerance boundary.

Let us examine the method of sorting out commodities for one tolerance boundary. If the acceptance tolerance is equal to the manufacturing one, the first contact of the transducer (Fig. 7) is adjusted to the given limiting size a; the second contact to size b which lies outside the field of tolerance and differs from size a by the amount of the limiting measurement error Δ_{lim}. If a signal "good" is received from the first contact, the commodity is passed as good. (In this instance the "seeping through" of a certain amount of faulty commodities whose sizes lie in the range from b to a is considered permissible.)

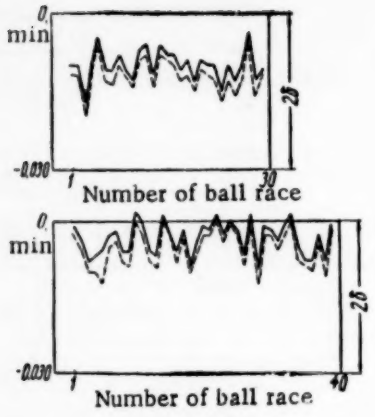


Fig. 8

A rejection signal from the first and second contacts shows that the size of the commodity is smaller than a; such a commodity is finally rejected and is not subject to rechecking. If the first contact signals a rejection and the second signals "good", the commodity becomes subject to rechecking, since in this case it should be concluded that its actual size L lies in the limits of:

$$a-2\Delta_{lim}<L<a+\Delta_{lim}.$$

Thus, with this system of contact adjustment practically all the commodities whose sizes are smaller than $b-\Delta_{lim}$ will be finally rejected. A part of the faulty commodities whose sizes lie in the range between c and a will also be rejected.

"False rejection" caused by the displacement of the center of grouping of the controlled sizes with respect to the middle of the tolerance field. When analyzing the measurement error effects on the sorting results, it was assumed that in all the cases the center of controlled size grouping coincided with the middle of the tolerance field. It is known that under mass production conditions, a displacement of the center of the size grouping of commodities with respect to the middle of the tolerance field often occurs due to various reasons, including an insufficiently careful adjustment of the equipment. If the commodity dimensions do not exceed the tolerance limits, the displacement of the grouping center cannot be considered as a breach of the accuracy of measurements. This circumstance can, however, cause a considerable increase in the amount of "false rejections," since with this displacement the probability of obtaining commodities with sizes close to one of the limiting values increases. Figure 8 shows the track accuracy of two consignments of inner ball races ground on a centerless automatic machine. The diagram shows minimum and maximum track diameters for various ball races. It will be seen from Fig. 8 that the consignments of the ball races under consideration, which were produced at different periods, have a dispersion zone of their track sizes smaller than the value of tolerance 2δ. In the first consignment of races, however, the center of the size grouping does not deviate appreciably from the middle of the tolerance range, but in the second consignment the grouping center is widely displaced towards the upper limit. This displacement is the result of an insufficiently careful grinding machine adjustment which lead to sizes of certain ball race tracks coming outside the tolerance limits. With a correct adjustment of the automatic grinder it would have been possible in this case to dispense with a hundred percent acceptance checking of the ball races; but if such a checking were still used, the number of "false rejects" would have been insignificantly small even with considerable measurement errors. In the case under consideration, the requirement of a hundred percent inspection is only due to errors in the adjustment of the automatic grinder, which, by the way, can be easily remedied. The amount of "false rejections" in checking ball races similar to the second consignment of Fig. 8 becomes very considerable.

Errors of automatic equipment adjustment. In many instances a considerable part of the total error of checking consists of the errors in adjusting automatic equipment to a required limiting value. These errors comprise the error of the adjustment of the automatic equipment itself, the errors of manufacture or setting of the gages, and errors of other testing equipment (dial instruments). When the automatic machine is adjusted in its measuring position for a limiting dimension by means of a setting gage, it is assumed that the transducer errors (more precisely, the errors of its operation) are distributed according to a symmetrical law. Thus, the position is considered to be correctly adjusted to a given size if the number of makes and breaks in the electrical circuit is the same when a corresponding sample is passed through the machine several times. The curve in Fig. 9 represents the relation between the operating adjustment error and the ratio of the makes and breaks of the transducer for repeated operation with a calibrated sample commodity. The values of the adjustment errors were calculated for a normal distribution of the operating errors of the transducer. The ratio of the number of times the contact was made to the number it was broken (or vice versa) is plotted along the x-axis of the graph in Fig. 9. The value of the transducer's error of operation expressed in fractions of the root-mean-square error of the transducer is plotted along the Y-axis. Let, for instance, a standard transducer whose root-mean-square error is 1 μ be adjusted within a range of 0-3 mm. When the calibrated sample was passed through the automatic machine fifty times, the transducer contacts were open 58 times and closed 42 times. In this instance the error of the operating adjustment

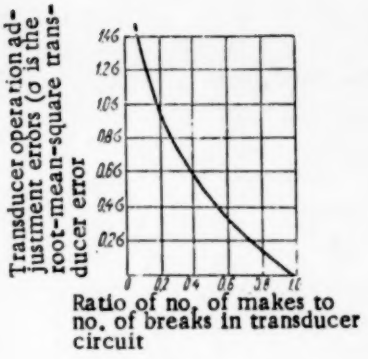


Fig. 9

amounted to 0.2σ, i.e., to $0.2\,\mu$ (Fig. 9). The accuracy of the operating adjustment of the transducer by means of gages does not depend directly on the accuracy of the adjusting screws. The transducer adjusting screws should nevertheless be made accurately and provided with a smooth action, since the quality of the screws determines the efficiency of the adjusting process.

For the adjustment of automatic control equipment with two limiting positions the following setting gages and dial instruments are used: a) two limiting gages (one for each tolerance limit) constructed with the appropriate degree of accuracy; b) two limit gages constructed with insufficient accuracy, but whose dimensions are calibrated with sufficient accuracy, used in conjunction with the transducer scale; c) one gage accurately constructed or accurately calibrated used in conjunction with the transducer scale.

The design of automatic control machines does not, as a rule, provide the possibility of using block gages as calibrated samples. For the adjustment of automatic machines, special gages in the shape of the commodities under test are used. Thus, in the change from manual to automatic control a new link arises in the chain of transferred measures. In adjusting automatic equipment by means of uncertified gages their manufacturing tolerances are fixed in such a manner that the required setting values are equal to the arithmetic mean of the maximum and minimum tolerances of the gages. In such a case the limiting errors of the setting gages (for each tolerance limit) will not exceed one half the manufacturing tolerance of the gage.

The setting gages for checking the external dimensions of the commodities are made, depending on the complexity of their shape, according to ISO quality 2-4, and the setting internal gages to quality 3-5. Modern measuring equipment provides very high grade calibration of the external dimensions of setting gages. Thus, the limiting calibration errors of gages up to 100 mm measured by means of a telescope caliper against 4th grade standards amounts to ± 0.5 to $\pm 1\,\mu$. Much higher calibration accuracy is attained when a contact interferometer and 2nd grade standards are used. If the ambient temperature during testing does not deviate from the normal by more than 1°C, the limiting calibration error of gages up to 50 mm does not exceed $\pm 0.15\,\mu$. The design of the measuring positions and the methods of adjustment of the automatic equipment should be such that the inaccuracies in the shape of the gages do not affect the precision of adjustment. The great accuracy of gage calibration cannot otherwise be used effectively.

One of the most accurate methods of automatically controlling internal dimensions is the pneumatic electrical-contact method. The high precision of the pneumatic device indications often make the main component of the total error of this method consist of the calibration error of the setting gages. Normally this calibration is carried out by means of horizontal telescope calipers with an error of $1\text{-}1.5\,\mu$. In order to increase the accuracy of pneumatic electrical-contact methods of controlling internal dimensions, the following design and method of calibration of a setting gage can be recommended.

The device consists of a block gage with an opening (Fig. 10). The axis of the opening is parallel to the measuring faces of the gage. The length L of the gage is measured by the absolute interferometer method with an error of $\pm(0.05 + 0.5 \cdot 10^{-3} L \text{ mm})\mu$. Dimensions l_1 and l_2, which do not exceed 10 mm, are measured by a relative method on a contact interferometer against 1st grade standards with an error of $0.12\,\mu$ (i.e., one third of the calibration error of the gages). For measuring dimensions l_1 and l_2 a special measuring end-piece is used (Fig. 10). The diameter of the opening in the face perpendicular to the measuring faces of the gage is

$$d = L - (l_1 + l_2).$$

With the above errors of measurements of dimensions L, l_1, and l_2, the maximum error of calibration of the opening diameter for d = 50 mm will not exceed $\pm 0.2\,\mu$. The accuracy of calibration of a pneumatic measuring transducer will be affected by the errors in the shape of the opening and the parallelism of its axis to the measuring faces of the gage. The effect of these errors will, however, be insignificant if the measuring nozzles' alignment is made to coincide with the gage cross section at which it was calibrated. The gage of this design should be used directly for adjusting the measuring position of the automatic control equipment. If this is impossible,

TABLE 3

Means of adjusting the automatic equipment	Dimensions, mm					
	1-6	6-18	18-30	30-50	50-80	80-120
	limiting errors of the adjusting equipment (in μ) ±					
Two second quality ISO gages without calibrations	1.0	1.0	1.0	1.5	1.5	2.0
Two fourth quality ISO gages without calibrations	2.0	2.5	3.0	3.5	4.0	5.0
Two gages calibrated by means of a telescope caliper against 4th grade standard gages; the instrument has graduations of 1 μ	0.6	0.8	0.8	0.9	0.9	1.2
Two gages calibrated by means of a contact interferometer against second grade standard gages; the instrument has graduations of 1 μ	0.5	0.6	0.6	0.6	0.7	0.7
One second quality ISO gage without calibrations; the instrument has graduations of 1 μ	1.5	1.5	1.5	2.0	2.0	2.2
One gage calibrated by means of a telescope caliper against fourth grade standard gages; the instrument has graduations of 1 μ	1.0	1.2	1.2	1.3	1.3	1.4
One gage calibrated by means of a contact interferometer against second grade standard gages; the instrument has graduations of 1 μ	1.0	1.0	1.0	1.0	1.1	1.2

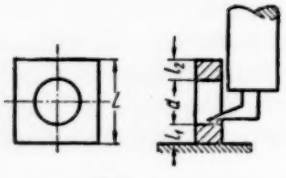


Fig. 10

owing to the design of the equipment, the special gage should be used for calibrating a working gage on a universal pneumatic instrument. Table 3 shows the maximum errors of the setting gages which are most commonly used in industry. In calculating the errors of the setting gages it was assumed that the manufacturing and calibration errors of the gages and the reading errors of dial instruments were distributed according to the normal law. The maximum error of reading of a dial instrument with graduations of 1 μ was assumed to be 0.5 μ. In calculating the total adjustment error of automatic equipment, which includes, in addition to errors of the adjusting instruments, also the errors of the adjustment proper, it is necessary to remember that when the transducer scale is used, the operating error will depend to a considerable extent on the design of this device.

If the transducer adjusting screws are used as the scale device, the adjustment of the automatic equipment by means of a calibrated gage is carried out in the following manner: The transducer is adjusted by repeatedly passing the gage through the automatic equipment and then the adjustment screw is displaced in the appropriate direction by an amount equal to the difference between the actual size of the gage and the given setting size. In this case the operating errors of the transducer have very little effect on the accuracy of the automatic equipment adjustment. If a lever instrument, which is attached to the transducer or incorporated in it, is used as a scale device, the adjustment of the automatic equipment by means of a calibrated gage is carried out in the following manner: The gage is placed in the measuring position and the dial instrument reading is noted; next the transducer measuring rod is displaced in the appropriate direction by an amount equal to the difference between the actual size of the gage and the given setting size, and then the adjusting screw is approached to the corresponding contact until the signal lamp lights. In this case it is no longer possible to check the adjustment by a repeated passing of the gage through the automatic equipment and the adjustment operation proper may attain, even with

TABLE 4

$\frac{\Delta_{lim}}{2\delta}$	The number of "false rejects" after four rechecks of the rejected commodities in the automatic equipment	The number of "false rejects" after four measurements and the averaging of the results
	in % of the total number of commodities in the consignment	
0.2	8	4.9
0.3	18	11

the most careful setting of the adjusting screw by means of the contact light, values equal to the limiting error of the transducer operation. This consideration also applies to amplitude transducers, which are adjusted in their overwhelming majority only by means of scale devices.

In order to raise the accuracy of the automatic control equipment adjustment it is necessary in the first place to strive for the reduction of transducer operating errors, the raising of the scale instruments' accuracy and the development of automatic measuring devices which provide the facility of using block gages for setting their operation.

The application of repeated measurements. The root-mean-square error σ_M of the arithmetic mean n measurements amounts to $\sigma_M = \sigma/\sqrt{n}$, where σ is the root-mean-square error of a single measurement. A method of increasing the measurement results' accuracy, based on this proposition and widely used in various branches of science and technology, is very seldom used in engineering for the following reasons.

This law holds when for each measurement the effect of all the factors which determine the accuracy of measurement is random and independent. The application of this method under different conditions will lead to the reduction of the effect on accuracy of only the factors which cause random errors in each repeated measurement. The nature of manual testing used in engineering makes the repeated measurements, which satisfy these conditions, very difficult to realize. Thus, the main components of the total error of relative linear measuring methods are instrument reading errors, end gage errors, and temperature errors. In repeated measurements of a certain quantity on the same instrument against the same standards at a constant temperature, the components enumerated above will appear as systematic errors and thus the accuracy of the arithmetic mean results will be increased by an insignificant amount only due to the decreased effect of secondary factors (errors of reading and in placing the commodities). Repeated measurement by means of several models of instruments and different block gages is difficult owing to the rapid drop in the productivity of checking thus produced.

Automatic as well as manual methods of checking linear dimensions are extant with respect to single measurements. The peculiarities of automatic control, however, based on the use of highly specialized high-speed measuring devices, lends itself to the application of repeated measurements.

The development of methods for determining automatically the arithmetic mean of several measurements of a dimension is not receiving sufficient attention, yet the theoretical possibility of such methods, based on the use of inductive, pneumatic-electrical-contact, and some other electrical means of measuring distances, has been demonstrated. Equipment for repeated measurement can be mounted on a common rack, providing for a practically simultaneous execution of all the measurements. Automatic systems, which check a given quantity in several positions and then average the results thus obtained, can also be devised. In this case the checking of commodities can be made without substantially reducing the speed of the automatic operation. The design of the machine in that case will be more complicated.

It is interesting to compare the efficiency of repeated control of rejected commodities without averaging the measurement results with a repeated control of all the commodities with an averaging of the results. Table 4 provides data for the following conditions: the ratios of the limiting errors of single measurements Δ_{lim} to the

manufacturing tolerance 2δ were taken as 0.2 and 0.3; normal distribution law was assumed for the controlled sizes and measurement errors; in the first instance commodities are rechecked four times without averaging the measurement results, and in the second instance they are measured four times and the average results obtained; the acceptance tolerance $2\delta_1$ is reduced at each limit as compared with the manufacturing tolerance by an amount equal to the error of measurement (in the first instance $2\delta - 2\delta_1 = 2\Delta_{lim}$ and in the second instance $2\delta - 2\delta_1 = 2\Delta_{lim}/\sqrt{4}$).

The productivity of the two methods of measurement will, naturally, be different, since in the first method only rejected commodities are rechecked, and in the second, all commodities are repeatedly measured.

Temperature errors of measurement. The most dangerous source of these errors is the difference in temperature between the controlled commodities and the measuring equipment. When steel commodities are measured, their temperature error amounts to about 1 μ in a 100 mm length per 1°C difference between the temperature of the commodities and that of the measuring equipment.

Manual production of precision articles is usually organized in such a manner that the temperature error is almost completely eliminated by keeping the commodities and the measuring equipment in the same ambient temperature long enough for their temperatures to become equal. Under automatic control of production this method of temperature difference elimination, which involves the accumulation of commodities, is hardly applicable, especially when large size commodities are produced. More often the equalization of the temperature of small and medium size commodities is attained in special machines used for their washing and drying. If the temperature of the commodities which leave the washing machine differs considerably from that of the automatic control machine, it is recommended to make the setting gages which are used for the adjustment of the equipment pass through the washing machine as well. Experience has shown, however, that when washing machines are used, the temperature measurement errors are often very large.

The development of a method of automatic temperature equalization when checking linear dimensions is, therefore, of considerable interest. Recently V. S. Chaman (Interchangeability Bureau) suggested a method of achieving it by means of thermal resistors and a specially designed transducer [2]. Immediately before measuring, the temperature difference between the surface of the commodity and the measuring equipment is obtained automatically and the measuring results automatically corrected for this difference. Before the commodity is fed to the automatic control equipment, it must remain at a given temperature only long enough to equalize the temperature within the commodity itself, which normally takes considerably less time than equalizing the temperature between the commodity and the automatic control equipment. Laboratory tests of this method produced good results and it will be first applied to automatic lines for making railroad truck axles [3]. The use of the temperature compensation method provides the possibility of placing, when required, the automatic acceptance inspection equipment nearer to the production machines, thus in many cases increasing the effectiveness of the inspection.

Editorial Note. The article does not deal with all the problems affecting the accuracy of automatic control; for instance, in the section "Errors of automatic equipment adjustment," the problem of raising the accuracy of the automatic control of components with a complex shape has not been dealt with.

The Editorial Board invites the readers of this journal to send articles dealing both with the question raised in this article and with other problems of measurement automation in various branches of our national economy.

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A SET OF MEASURES AND INSTRUMENTS FOR MOBILE AUTOMOBILE LABORATORIES

B. N. Vorontsov

The Gor'kii State Inspection Laboratory of Measuring Equipment has developed and produced a set of measuring devices conveniently portable and especially suited for automobile laboratories.

Names of gages and devices	The purpose for which they are used	Number of pieces
End gages from 5.12 to 200 mm, 5th grade, 0-25 mm	Checking micrometers and slide gages	10
Angle gages 15°10' to 90°, 2nd class	Checking universal angle gages	7
Smooth micrometer, 0-25 mm	Checking of slide gages	1
Special micrometer, 0th class	Checking clock type extensometers	1
Device for checking micrometers larger than 100 mm	Checking micrometers larger than 100 mm	1
Device for checking lack of parallelism in micrometers larger than 100 mm	Checking micrometers larger than 100 mm	4
Device for checking indicating internal calipers	Checking indicating internal calipers from 6-250 mm	1
Flat glass plate	Checking measuring faces of instruments	1
French curve rule, 100 mm	Checking measuring faces of instruments	1
Tape comparator meter	Checking bar length gages	1
Micrometer holder	Fixing the micrometer for checking	1
Textolite clamps	Dismantling microscrews when adjusting their zero position	1
2nd grade hardness gages	Checking hardness testers type TK	5
Hardness standard HB 190 ± 25	Checking hardness testers type TSh	1
Special scale L = 6 mm, graduated in 0.5 mm	Checking microscopes (Brinell lenses)	1
Screw drivers	Fixing vernier scales and other work	2

Figure 1 shows the general view of the set designed for checking universal linear measuring instruments and instruments for measuring the hardness of metals, both of which are most frequently used in the work of mobile laboratories.

Fig. 1

Fig. 2

A special container 350 × 280 × 160 mm holds gages and checking devices listed in the table.

The total weight of the container with the set of instruments does not exceed 7 kg.

The end and angle gages are made to special order, and the nominal values of their lengths and angles correspond to the check points quoted in the specifications.

Thus, end gages of the following nominal values are included: 5.12, 10.24, 15.50, 21.36, 25.0, 50.0, 75.0, 100.0, 150.0, and 200.0 mm.

Angle gages have the following values: 15°10', 30°20', 45°30', 50°, 60°40', 75°50', and 90°.

These gages are much more convenient and efficient in use than ordinary sets, since for the checking of 25 mm micrometers combinations of gages are not required, and micrometers over 25 mm are easily covered by combinations of two gages.

Such gage values considerably simplify the checking of instruments and reduce the number of standard gages required in a set designed for mobile laboratories.

The set includes a device developed by the author for checking portable dial inside calipers and replacing existing devices which are too heavy and inconvenient and are actually designed for stationary use.

The construction of the device for checking dial inside calipers is shown in Fig. 2 and consists of a square with sides of 125 × 110 mm, whose slots carry clamps for holding the inside calipers under test and a micrometer by means of which the dial gage measuring spindle displacement is checked.

The clamps can be fixed to the sides of the square in any position within the limits for checking indicating hole gages of 6-250 mm, which completely covers the most common sizes of these gages.

The clamp jaws have V-shaped grooves cut in them whose axes are in the same plane, so that when the hole gage and the micrometer are fixed in the position shown in Fig. 2 their measuring spindles are placed along the same axis, thus facilitating the adjustment of the device in the working position. Practical use of this device showed its applicability for checking lever and dial type extensometers with graduations of 0.01 mm.

In the first instance, the extensometer is fixed directly in the clamp; in the second case, it is first mounted in the hole of a cylindrical holder 15-20 mm in diam and 80-100 mm long. The holder is fixed in the clamp in such a manner that the extensometer hole is placed along the same axis as the micrometer spindle.

The capability of checking three types of instruments by means of one device provides an even more compact set of checking instruments and gages than the one shown in Fig. 1.

The specially made micrometer grip fixed to a mounting plate on the front of the case (Fig. 1) is especially useful.

The set of checking gages described in this article should be purchased by every State Inspection Laboratory which has a mobile laboratory. The set can also be used by state inspectors for inspections of small and medium size establishments and the sets of gages and devices for checking hole gages can be used successfully for practical work in any Central Test Laboratory or Control Station.

Editorial Note. The supply of this set of checking gages to mobile laboratories is expedient, but is should be supplemented with a lever type micrometer and a device for testing the measuring effort of micrometers.

OPERATING TIME OF PNEUMATIC MEASURING SYSTEMS

A. P. Kurochkin and F. V. Tsidulko

Each pneumatic system of the manometric type used for measuring dimensions of commodities has a measuring chamber connected to a liquid or spring type manometer. The air enters the chamber through an inlet nozzle and leaves through the measuring nozzle which forms, with the component under test, the so-called measuring gap. Each value of the measuring gap corresponds to a definite value of the pressure in the measuring chamber. When the measuring gap is changed from its initial position S', corresponding to the absence of a component in the gap, to value S", corresponding to the dimension of the component, the measuring pressure will also change accordingly. This change in pressure cannot occur instantaneously owing to the elasticity of the transmitting medium, air; the measuring pressure will change gradually until a balance is reached between the flow of air through the inlet nozzle and the measuring gap. The duration of this process, i.e., the operation time, which is determined by the speed with which the measuring chamber is filled through the inlet nozzle and the speed of its simultaneous evacuation through the measuring nozzle, depends on the air pressure in front of the inlet nozzle (the so-called working pressure), the diameter of the inlet nozzle, diameter of the measuring nozzle, measuring chamber volume, and the construction of the manometer. The operation time decreases with an increase in the inlet diameter, a drop in the working pressure, and a smaller measuring nozzle, measuring gap, and chamber volume.

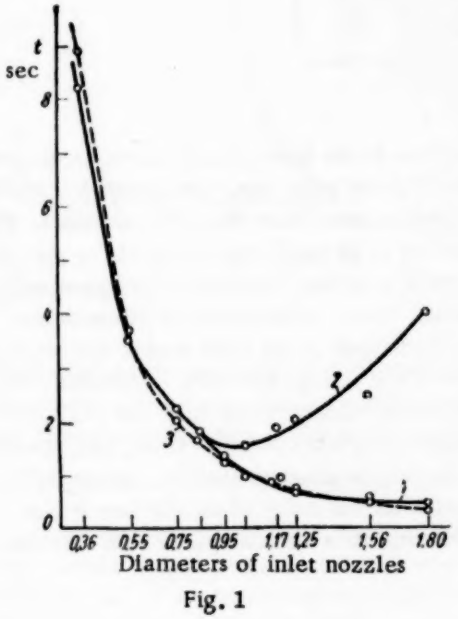

Fig. 1

The operation time of a "Solex" instrument was determined in the Interchangeability Bureau experimentally for all the possible working conditions at the point of the greatest manometer sensitivity, i.e., at 37.5 cm of its scale, with a number of input nozzles of 0.35 to 1.80 mm in diameter and with measuring nozzles of 1, 1.5, 2, and 3 mm internal and, respectively, 2, 3, 4, and 5 mm external diameters. The operation time was measured with a stopwatch. The relation of the operation time to the diameter of the inlet nozzle is shown by curve 1 in Fig. 1.

With small inlet nozzles the level of the liquid dropped, when the measuring gap was "instantaneously" changed, from the top part of the scale, where it was originally, to its final position at 37.5 cm, where it remained without any noticeable variations.

As the diameter of the inlet nozzle was increased, the sequence of events gradually changed. The time taken by the liquid column in reaching the point at 37.5 cm was gradually reduced, but after reaching the point the liquid level, owing to the speed of its movement, did not remain there, but went even lower and finally settled at the 37.5 cm point after several oscillations about this point with progressively decreasing amplitudes.

Exp. no.	Inlet nozzle diameter, mm	Measuring nozzle diameter, mm	Working pressure, kg-wt/cm²	Measuring gap, μ	Contact operation time, sec
1	0.55	1.50	1	35	3.1
2				50	3.5
3				60	3.5
4			1.5	50	4.5
5	0.80		1		1.4
6			1.5	25	1.3
7				50	1.8
8				70	1.8
9		2.00	1	50	1.8
10				100	2.7
11			2	50	2.0
12				100	2.9
13	1.20		1	80	0.9
14				100	1.0
15				140	1.1
16				180	1.4
17			1.5	80	1.1
18				100	1.3
19				140	1.4
20				180	1.5
21			2	80	1.3
22				100	1.5
23				140	1.5
24				180	1.7
25	1.60		1	100	0.9
26				200	1.1
27			2	100	0.8
28				200	0.9
29	2.20			100	0.2
30				200	0.3
31				400	0.3
32				500	0.4

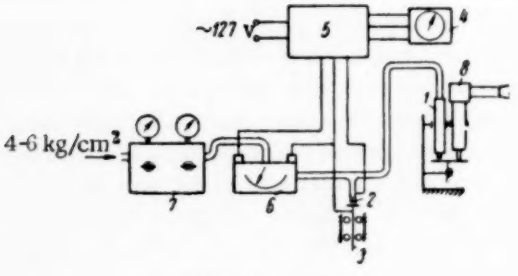

Fig. 2

With a further increase in the inlet nozzle diameter, the time taken to reach the 37.5 cm point again decreases, but the duration of damped oscillations about this point increases. This phenomenon is similar in its origin and character to the damped oscillations of a pointer instrument with an elastic (spring) transmission. These characteristics of operation time variations with changes of the inlet nozzle diameter can be traced on curves 1 and 2 (Fig. 1): curve 1 represents the time taken by the liquid column in reaching the 37.5 cm point and curve 2, the complete operation time, i.e., the total time, taking the damped oscillations into account as well.

It should be noted that with large inlet nozzle diameters the time required for the delay of oscillations is considerably larger than that required to reach the 37.5 point. The experimental data was compared with calculations obtained from the following equations [1]:

$$t = 6.40 \cdot 10^{-7} \frac{F_M}{F} \sqrt{H^3} \left[\frac{1}{H} \left(\frac{V}{F_M} + 1033 \right) - \frac{h'}{H} + 1.5 \right] \left[6.48 + \lg \frac{\left(1 - \sqrt{\frac{h'}{h''}}\right)\left(\sqrt{\frac{H-h'}{H-h''}} - 1\right)}{\left(1 + \sqrt{\frac{h'}{h''}}\right)\left(1 + \sqrt{\frac{H-h'}{H-h''}}\right)} \right],$$

where H = 50 cm of water column is the working pressure; h' is the measuring pressure (in cm water column) corresponding to the initial measuring gap equal to infinity, and h'' is the final measuring pressure; t is the operation time, sec; F is the cross-sectional area of the inlet nozzle, cm^2; F_M cross-sectional area of the measuring tube, cm^2; V the measuring chamber volume, cm^3.

A good agreement between the experimentally obtained and calculated operation time shows that the effect of the liquid column inertia, which is not taken into account in the formula, is small and can be neglected.

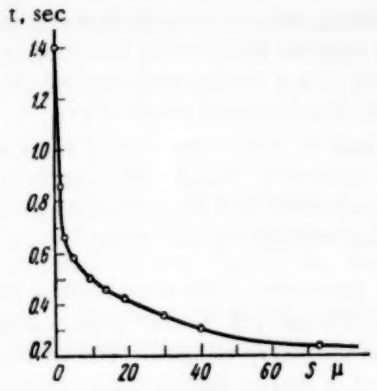

Fig. 3

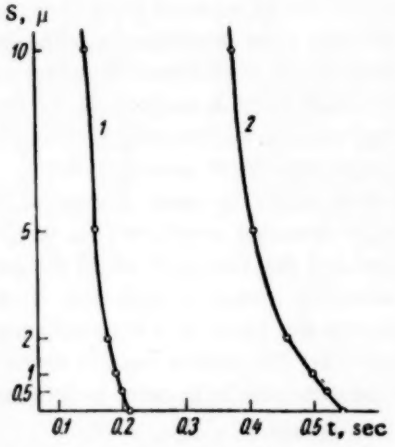

Fig. 4. 1) Sluggish diaphragm; 2) elastic diaphragm.

Particular attention should be paid to the effect of the internal diameter of the measuring tube. A decrease in the diameter should, according to the formula, lead to a sharp drop in the operation time. In this connection arises the idea of designing pneumatic circuits with $F_M \to 0$. A pneumatic circuit which approaches this requirement is the one with a diaphragm transducer working at a low pressure.

Figure 2 shows a schematic of a test equipment for measuring the operation time of high-pressure instruments with spring (bellows) pressure gages. An "imitating" nozzle 2 of the same size as the measuring nozzle 1 is connected in parallel with it. The heel of a rod on moving carriage 3 is fixed opposite nozzle 2; when the heel is removed from the "imitating" nozzle 2 the preliminary "infinitely large" measuring gap S' is simulated; when the heel moves into contact with the nozzle only the permanent measuring gap S" of nozzle 1 remains open.

Time intervals were measured by means of an electrical timer 4 with 0.01 second graduations, designed to measure intervals between two electrical pulses. The "imitating" nozzle and its heel are insulated from each other and connected to the grid contact circuit of the electronic unit 5. When nozzle 2 is closed by its heel, it makes an electrical contact with it, bringing in operation the measuring gap S" and at the same time producing a pulse which triggers the timer. The timer is stopped by the closing of the tested transducer 6 contacts. The operation time of the electronic relay is measured in hundredths of a second and can be neglected as compared with the operation time of the pneumatic mechanism. The air is supplied through a filter and stabilizer unit 7. The measuring gap is evaluated by means of a telescopic height gage 8.

In order to cover as wide range as possible of various practical applications of the bellows transducer, its operation time was determined with inlet nozzles of 0.55, 0.80, 1.20, 1.60, and 2.20 mm in diameter, and measuring nozzles with internal diameters of 1.5 and 2 mm and respective external diameters of 3 and 4 mm. With a working pressure of 1, 1.5 and 2 kg-wt/cm^2, the measuring gap was set for a series of values covering the entire linear range of the characteristic corresponding to each combination of the enumerated parameters.

The table shows the operation time data of bellows transducers.

An increase of the inlet nozzle diameter speeds up the filling of the measuring chamber, but larger measuring nozzles or gaps produce an opposite effect. With a larger measuring chamber volume and pressure a longer time is required for measuring the amount of air, providing other factors remain the same. Hence, in order to decrease the operation time, it is necessary to strive for a larger inlet nozzle diameter, a smaller chamber, shorter connecting hoses, a lower working pressure, and smaller measuring nozzles and gaps. It should be remembered that the transmission capacity of the stabilizer or stabilizers should be large enough to provide the required flow of air, since with large inlet and measuring nozzles, a high pressure (up to 2 kg-wt/cm^2), and a large number of measuring nozzles, an insufficient output from the stabilizer begins to increase the equipment's operation time.

In practice, however, it is not always possible to increase the diameter of the inlet nozzle, decrease that of the measuring nozzle, and reduce the working pressure and the chamber volume. In this connection it is possible to point out two methods of reducing the operation time: isolation of the measuring chamber when there is no component in the measuring position, and a dynamic adjustment of transducers.

The first method, that of a complete or partial preservation of the measuring pressure in the chamber when there is no component in the measuring position, requires a mechanical isolation of the measuring chamber. The isolation of the measuring chamber both from the atmosphere (covering up of the measuring nozzle) and from the

working pressure chamber (covering up of the inlet nozzle) is the most effective, since this preserves the measuring pressure in the chamber. If the measuring nozzle alone is covered up, working pressure is established in the measuring chamber and hence, when the measuring nozzle is opened, time is required for reducing this pressure to the level of the measuring pressure. Tests have shown, however, that in such case a considerable amount of time is saved, providing there is a certain relationship between the parameters. One example of the practical implementation of this principle is a contact measuring tap, in which a ball or cone of the closing valve automatically (under the air pressure) closes, either completely or partially, the measuring nozzle when there is no component in the measuring position. Another method which was tried out successfully in practice consists of the installation of a throttle in front of the measuring nozzle. This, however, slightly reduces the sensitivity.

Another method of reducing the operation time is derived directly from the nature of the experimental curves obtained. It was found that the displacement of the transducer's moving contact is delayed, so that it takes 50% of the operation time to complete the last few microns separating the moving and stationary contacts. The character of this relationship is illustrated by the curve in Fig. 3. In applying this method, a strictly defined time, smaller than the operation time, must be allocated to measurement. For such a dynamic adjustment the stationary contact should be moved away from its static position towards the moving contact. With this adjustment the contacts will meet before the pressure in the measuring chamber is stabilized, i.e., the contact will be made at some intermediate point along the curve of Fig. 3 instead of at the end point. However, if the time spent in measuring, adjustment, and operation is the same, the measurement will be completely accurate. The main defect of this method, which consists in the necessity to "measure off" the time required for measurement, should not serve as an obstacle for its application since the steepness of the end portion of the curve makes even large errors in determining time result in negligibly small errors of displacement. Thus, the main advantage of dynamic adjustment consists of eliminating the problem of the operation time, and making it possible to measure in an arbitrarily small interval of time. Another advantage of this method consists of making the adjustment under operating conditions. In fact, in the ordinary static adjustment the stationary contact is moved slowly, eliminating the inertia effect of the system, whereas, in operation, the transducer's system is displaced rapidly and its inertia cannot be neglected. Tests have shown the existence of this error in static adjustment. In dynamic adjustment this effect is eliminated since the conditions of adjustment and operation are identical. It is, however, possible that the random error of measurement is increased in this method, it is therefore necessary to carry out special experiments in order to determine the advisability of using this method.

Diaphragm transducers can operate both in high and low pressure systems. The generally accepted opinion that in high pressure systems these transducers operate "instantaneously" has not been confirmed in tests. On the contrary, it was established that the general operating characteristic of these transducers is similar to that of bellows transducers, and that all the numerical data obtained for bellows transducers is applicable to diaphragm transducers, providing elastic diaphragms are used.

The general operating characteristic of these transducers is preserved when they are made to operate at low pressures but the operation time is reduced to 0.2-0.1 of its previous value. The replacement of the elastic diaphragm by a sluggish one leads to a sharp reduction in the operation time (Fig. 4). This phenomenon is due to the elasticity of the diaphragm providing a considerable resistance to its displacement by the small forces involved in low pressure systems.

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SELECTING A METHOD OF REFERENCE IN MEASURING THE UNDULATION OF ANTIFRICTION BEARING RACES

V. V. Matveev and V. L. Ryaskov

The working properties of antifriction bearings depend to a great extent on the accuracy of the geometrical parameters of their components. Life tests of bearings carried out at the 1st State Bearing Plant (GPZ) showed that precision bearings made of the same material as ordinary bearings have a much higher efficiency factor.

The precision of the bearing components is determined by the accuracy of dimensions, precision of the geometrical shape, appropriate relative positioning of surfaces, their undulations, and finish.

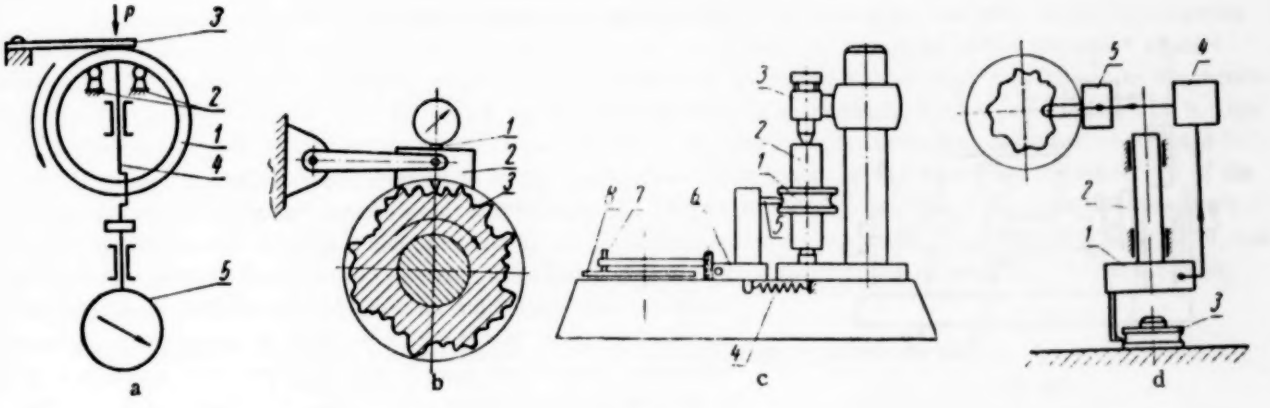

Fig. 1

The accuracy of dimensions, precision of the geometrical shape, relative positioning of surfaces, and the finish of antifriction bearing components' surfaces are determined by appropriate specifications. There are, however, no specifications for surface undulations and there is no recognized method for testing them. This is mostly due to the difficulty of measuring undulation. Large distances between the irregularities and the unevennesses of undulations in different sections of the surface, both with respect to their height and length of waves, prevent the use of normal surface-roughness measuring instruments and make the development of special instruments, whose characteristics correspond to the dimensions under test, necessary.

In developing a wave recorder, it is important to choose correctly the method of reference of the probing system. All the means of measuring undulation can be divided by their method of reference into two groups: namely, those referred to the measured surface (Fig. 1a, 1b) and those referred to a standard surface (Fig. 1c, 1d).

Figure 1a shows an instrument with spherical bearings [1]. The tested ball race 1 is pressed against the spherical bearings 2 by spring 3. Spindle 4 touches the tested surface of the ball race and is connected to extensometer 5, which has 0.5 μ graduations. When the ball race is revolved, the extensometer reading provides an indication of the extent of undulations.

The author of [1] recommends an instrument for measuring undulations of ball race tracks, and asserts that errors due to referring measurements by means of two spherical bearings to the surface under test do not affect appreciably the measurement results. It is impossible to agree with this statement. Let us examine the case when the measuring spindle and the spherical bearings touch simultaneously the protrusions of the undulated surface (Fig. 2). When the bearings touch the regular circumference (at points A and B), the instrument reads the real height of the irregularity $X = H_B$. But since the bearings are assumed to be touching the protrusions of the undulated surface, the race is displaced with respect to the instrument by the amount $OO_1 = AA_1 = BB_1$.

The reading of the instrument will then be

$$X_1 = H_B - AA_1.$$

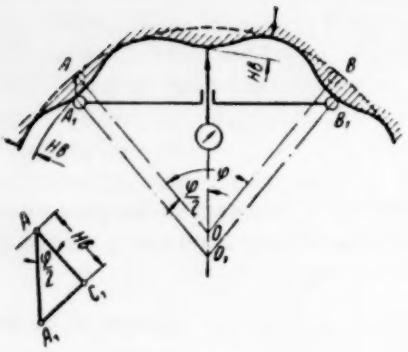

Fig. 2

Since the ratio of the length of the wave to its height is large, it is possible to consider small portions of the theoretical circumference and undulating surface curves as two parallel straight lines. Then we obtain from triangle AA_1C_1:

$$AA_1=H_B \sec \frac{\varphi}{2},$$

and the instrument readings become:

$$X_1=H_B\left(1-\sec\frac{\varphi}{2}\right).$$

Thus, when the measuring spindle actually touches a protrusion in the surface, it indicates a depression with a depth of:

$$X_1=H_B\left(1-\sec\frac{\varphi}{2}\right).$$

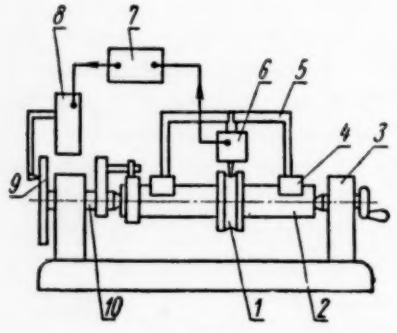

Fig. 3

Another version of an instrument of the first type is shown in Fig. 1b and consists of a wave recorder with an additional supporting "shoe". The measuring head 1 is fixed to a swiveling support ("shoe") 2 whose surface covers several wave lengths and is shaped to fit the diameter of the measured surface. In moving along the sample 3 surface, "shoe" 2 only touches the most protruding crests of waves. The surface passing through these crests serves as a reference for the oscillations of the measuring head 1 spindle. The author of the present article attempted to measure undulations by means of such a supporting "shoe." His attempts, however, were not successful owing to the difficulty of referring to a toroidal shaped track of a ball race. Better results in recording undulations of cylindrical components are obtained by using a standard surface.

The wave recorder type KP-14 of the Experimental Scientific Research Institute of the Bearing Industry (Fig. 1c) uses a reference to the surface of journals. The ball race 1 is fixed on mandrel 2 between two pointed journals 3. Test spindle 5 fixes to sliding support 6 and presses against the tested surface by means of spring 4. The displacement of support 6 is transmitted by means of a system of levers to needle 7, which records the undulations on the soot-covered surface of plate 8, which rotates in synchronism with component 1. Such a reference method cannot be considered expedient since the instrument will indicate the wobble in the bearings and the sum of the eccentricities of the mandrel with respect to the journal axis and the ball race track with respect to the mandrel surface. Thus, when reference is made to the journal axis, it becomes impossible to determine the eccentricity of the ball race track with respect to the fitting surface of the bearing, yet this eccentricity is an important parameter with strictly specified technical requirements.

The Taylor-Hobson "Taluround" [3] instrument uses the surface of a precision axle as its reference. The principle of its operation is shown in Fig. 1d. The electrical displacement indicator 1 fixed to the precision axle 2 rotates about the stationary object 3 under test which is firmly fixed to the instrument table. The indicator signals are amplified by amplifier 4 and fed to the recording device 5. The instrument has a device for precision centering of the tested object with respect to the axis of the axle. The error in the rotation of the axle, according to the company's data, does not exceed 0.08 μ.

In evaluating this reference method it is necessary in the first instance to note the technological difficulties of attaining a precision rotation of the axle. Moreover, the accuracy of the axle rotation will decrease in time, owing to wear.

A. N. Puzyr'kov, V. V. Matveev, and V. L. Ryaskov designed a wave recorder which uses the surface of a mandrel as a reference. Its schematic is shown in Fig. 3.

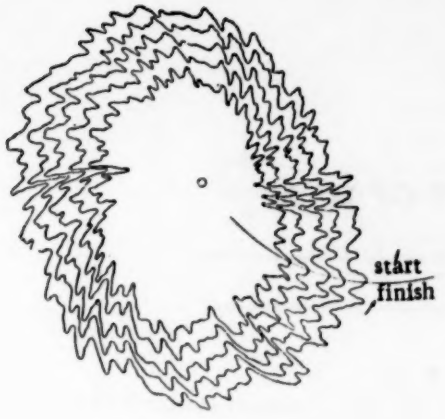

Fig. 4

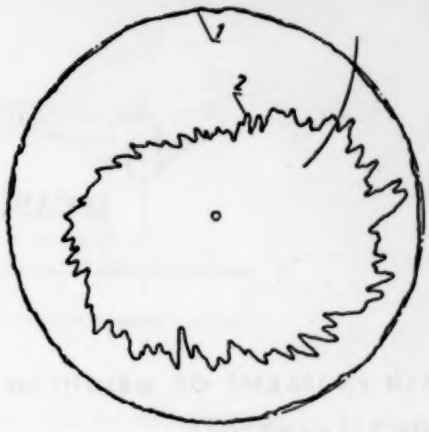

Fig. 5

Ball race 1 is placed on mandrel 2 which rotates in journals 3. A pi-shaped bracket 5, with a differential capacitance transducer 6 fixed to it, rests on the surface of the mandrel by means of its two getinaks* shoes 4 shaped to half surround the mandrel. Pulses from the transducer are transmitted through amplifier 7 to the recording device 8, which records the undulations, by means of an electric spark method, on paper fixed to disk 9. Disk 9 is fixed to a revolving spindle 10 which drives, by means of a dog-type transmission, the mandrel with the ball race under test. The pi-shaped bracket is hinged to the instrument stand and can follow all the vibrations of the mandrel. Thus, the mandrel wobble has no effect on the transducer indications. The instrument has three values of radial amplification: 4000, 6000, and 10,000,which correspond to three measurement ranges of ± 15, ± 10, and ± 5 μ. The maximum measurement error is 0.17 μ. The measuring effort of the transducer is P = 30 ± 5 g-wt. The radius of the measuring tip sphere is 2.5 mm.

The instrument provided a high consistency of undulation diagrams when the surface of a sample over a given section was repeatedly recorded (Fig. 4).

Figure 5 shows an undulation recording of the mandrel 1 and of the ball race 2. The undulation recording 1 of the mandrel is compared with a regular circumference. Its insignificant deviations from the circular form confirm the correctness of the selected reference method.

The undulation diagrams in Fig. 4 and diagram 2 in Fig. 5 provide a clear picture of the height, size,and number of undulations and determine accurately the differences in wall thicknesses (the eccentricity of the ball race track with respect to the fitting surface) and the deviation of the ball race from a circular to an oval shape.

CONCLUSIONS

In comparing the suggested reference method with those previously used,it is possible to note its following advantages: When recordings are made with reference to the mandrel surface, it is possible to determine the size of undulations, deviations of the ball race track from a circular shape to an oval one and its eccentricity with respect to the fitting surfaces; since the mandrel wobble does not affect the transducer indications, strict tolerances are not required for the accuracy of the journals and the eccentricity of the mandrel surface with respect to the axis of the journal points; in operation, the gap between the mandrel and the supporting shoes is automatically reduced and, in time, the shoes become better fitted to the mandrel surface.

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* Trade name for Russian insulating material — Publisher's note.

** See English translation.

MEASUREMENTS OF MASS

CERTAIN PROBLEMS OF WEIGHING TECHNIQUE IN RAILROAD TRANSPORT

K. N. Malakhov and V. N. Korotkov

In the postwar period from 1946 to 1958 our railroads received a large number of new 100-ton car weighbridges, which were installed at railroad stations and factory branch lines. In recent years, however, the construction of these weighbridges has decreased to a certain extent.

One of the reasons for the reduction in their manufacture is their obsolescence. Their insufficient maximum load is acting as a brake on the introduction of cars with a carrying load of 90-100 tons, and their low productivity reduces the car turnover and raises maintenance costs.

Under the present technological conditions the weighing lasts some 2.5-3 minutes. When the loading of cars by manual labor took up to 2 hours, the relative time spent on weighing amounted to 2-5%. At present mechanized loading is prevalent and it now takes 6-30 minutes to load a car, depending on the mechanization method used, and hence the relative weighing time reaches 15-30%. In this connection the need arises for a radical improvement in the weighing equipment.

Many innovations in the design of car weighbridges were suggested by worker-inventors engaged in weighing operations. Former chief weighing equipment inspector of the Moscow railroad, Com. Akinfiev, improved the switching of the VPP-100 weighbridge by eliminating the possibility of a displacement in the knife-edge bearing of the uneven-arm beam lever with respect to the lower double shackle block. It will be seen from Fig. 1 that the suspension rods with the stirrup, which supported the uneven-arm beam lever, have been replaced by connecting rods 1, whose lower portions are joined to each other by crossarm 2, which supports lever 3. A fixed position of the crossarm with respect to the lever is provided by two horizontal rods 4, which join the crossarm to the lever. The middle part of the crossarm has a hole which engages with pin 5, fixed to the end of the uneven-arm lever.

The joints between the siding and the platform rails are the most vulnerable parts of weighbridges. When cars pass over these joints, shocks are produced which cause increased wear and damage to the knife-edge bearings of the main levers and pillow blocks. These shocks also cause damage to the foundation walls, make the framework beams sag and force the siding rails away from the weighbridge. The weighing equipment inspector of the Syzran' section of the Kuibyshev railroad, Com. Tanyga, developed and installed in the Klyuchiki station weighbridge crossover pieces consisting of forged oval bars freely placed in sockets of special plates, bolted to the ends of the rails. Chief inspector of the Moscow railroad weighing equipment, Com. Kharlamov, developed and installed in the Ugresh station weighbridge a crossover piece in the form of a steel shoe which is bolted to the foundations of the siding rails. Other types of crossover pieces which provide a smooth running for the wheels over the rail joints are also known.

Railroad weighing equipment innovators cannot, however, eliminate the radical defects of the car weighbridges whose design has not changed for the last 50 years or more. The weighbridges now being produced are only designed to weigh cars in a stationary position and, for more accurate weighing, uncoupled from other cars. Their weighing is not combined with any other productive operation. The weighing expenses, are, therefore, very large. The manufacture of car weighbridges costs 200-300 thousand rubles each, yet their operating expenses amount to 300 thousand rubles each per annum when 100 cars are weighed per day.

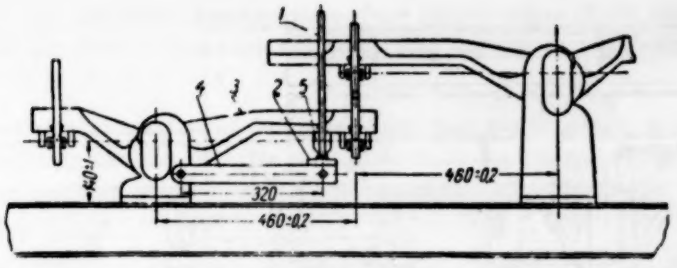


Fig. 1

There exists a radical manner of reducing the car weighing time and expenses involved by producing and using weighing instruments which can weigh moving cars automatically and record their weight.

An automatical recording instrument for dynamic weighing of cars at each axle was made in the Soviet Union as early as 1939. It was tested at one of the stations of the Leningrad junction and again in 1949 at the Moscow goods station of the Ryazan' railway. These scales were not as yet technically perfect: the speed of the weighed car was limited to 2.7 km/hr; the weight of the car at each axle was not summed up and had to be calculated by the weighing personnel; and the scales had an error exceeding the tolerance specified for car weighbridges (0.1%).

In subsequent years, however, the personnel of the weighing equipment plants and scientific research institutes did not seem to have devoted a lot of time to the improvement of car weighbridges or to the problem of their automation. It is true that in 1952 a sample car weighbridge with a dial indicator and a recording device was installed at the Ugresh station of the Moscow railroad, but this experiment was unsuccessful.

Abroad (the US in particular) electrotensometric scales are being used for weighing and automatically recording the weight of moving cars.

Our development engineers are also working on the design of electronic scales. Under the guidance of Com. Buzhinskii, the Nevskii Chemical Combine in Leningrad is designing tensometric scales for static weighing of railroad cars.

On an order from the Ministry of Railroads of the USSR, the Scientific Research Department of the Odessa Polytechnical Institute is developing new electronic car scales. These scales are designed to automatically record the weight of moving cars.

Contrary to the previously used circuits for electrotensometric weighing, consisting of bridges automatically balanced by means of a slide wire connected to a phase sensitive motor, the new scales use a system of automatic discrete compensation of four arm bridges. This circuit extends the life of the apparatus, increases its sensitivity, and provides high-speed weighing (of the order of 0.2 sec).

In order to speed up and cheapen the weighing operations on railroads, it will be necessary, in addition to the development of tensometric scales, to also automatize truck, crane, and goods scales, so that weighing of goods could be combined with basic technological operations.

The auto-truck scales should automatically record the weight of a moving truck with a trailer. Crane scales should automatically record the weight of containers and other heavy loads during their loading. Goods scales should be designed to facilitate their use in conjunction with auto-trolleys for automatically weighing and recording the weight of goods by subtracting from the total the weight of the trolley.

The improvement of the repair equipment and technical maintenance of the weighing equipment is also of great importance.

The existing stationary and mobile weighing equipment repair shops completely satisfy the requirements of the railroad and siding establishments.

Moreover, in 1952 all the mobile weighing equipment repair shops were installed in two-axle cars with stove heating, and by the beginning of 1959 many of these shops were installed in four-axle cars with water heating.

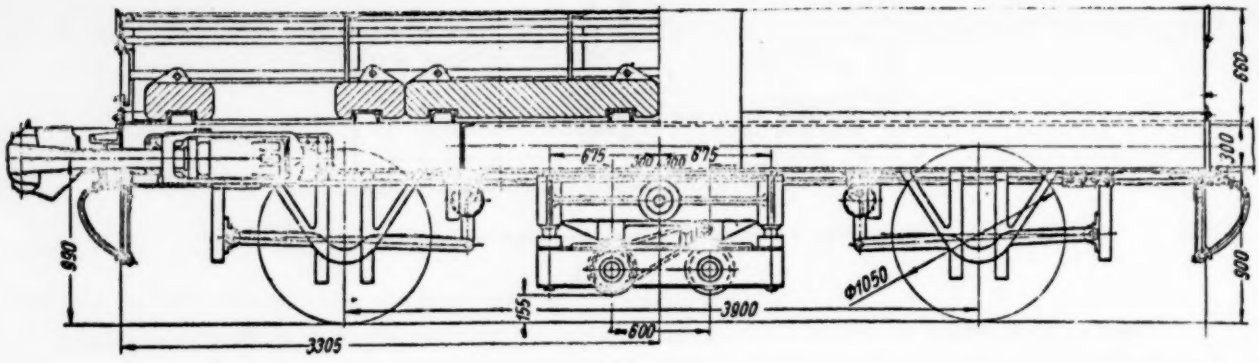


Fig. 2

Due to fuller use of the weighing-apparatus repair equipment, the technical condition of the weighing equipment has improved, thus making it possible to review the cycle of inspections and organize the technology of its repairs.

In the repair of railroad weighbridges, mechanization is now widely applied. Previously, long preparatory operations were necessary for the lifting of the weighbridge platforms: cutting sleepers, laying casings, and placing lifting jacks, requiring some 16 man-hours. On suggestion of the weighing equipment inspector of the Kursk section of the Moscow railroad, Com. Voskoboev, and the foreman of the Lyublino station locomotive depot, Com. Kaplev, a lifting device was constructed, which consists of a hydraulic jack mounted on two hinged stands which are fixed to the end of the rails. The jack rod supports an uneven-arm lever with pulleys through which runs cable with a crossarm for fixing to the rails. The device weighes 80 kg, can lift 5 tons to a height of 1300 mm, and requires less than 5 man-hours for the lifting and lowering of one weighbridge platform.

The VPP-100 weighbridge levers are lifted by means of a beam-crane with hand-tackle designed by a weighing crew foreman of the Krasnodar section of the North-Caucasian railroad, Com. Stetsenko. The beam-crane is mounted on the internal weighbridge supporting beams.

In repairing the weighbridges electrically operated tools are widely used, such as electrical drilling machines, portable grinding machines, etc. The use of electrical equipment has become possible owing to the electrification of a number of repair shop cars.

In 1958 our railroads received new weight checking platform cars equipped with automatic coupling.

The defect of the existing method of checking and adjusting weighbridges by means of weight checking platform cars consists in applying a load of 12.5 tons on each pair of levers, whereas during the weighing of heavy cars each pair of levers has to carry 30 tons.

The chief technical inspector of the Chelyabinsk State Inspection Laboratory of Measuring Equipment, Com. Mikhailov, mounted, in the middle portion of the platform, mechanical jacks by means of which each pair of levers is loaded during adjustment by the whole weight of the platform.

This method has been improved by the chief engineer of the Committee of Standards, Measures, and Measuring Instruments, S. I. Gauzner, who suggested equipping the checking platform with a jack trolley (Fig. 2) with a base of 600 mm. Owing to the use of the trolley, it is no longer necessary to lower and lift the entire platform over each pair of levers. The weight checking car is moved over the weighbridge platform by means of a manual drive. Checking by means of a concentrated mass of 25 tons provides a higher measuring accuracy for weighbridges and reduces the labor required for their adjustment.

The weighing apparatus checking equipment is being shortly supplemented by a laboratory installed in a four axle body of a passenger car and by a weight-checking four axle freight car. The laboratory car will be equipped with 11-12 standard scales of the I, II, and III grade.

The weight checking car will carry weights up to 2 tons and will be equipped with a crane for loading and unloading the trolley used for moving the weights along the weighbridge platform.

Serious attention is being paid to the improvement of the qualifications of the workers engaged in weighing. The Ministry of Railroads of the USSR is systematically organizing and conducting courses for gravimetric workers and training new personnel.

In conducting the technical renovation of the railroad weighing equipment, it is necessary to introduce at the same time certain alterations into the effective rules of determining loads. It is not correct to specify for all types of loads and means of weighing one and the same tolerance of 0.1%. It would be more correct to establish differentiated tolerances according to the type of loads, as is customary in international practice.

Editorial Note. K. N. Malakhov and V. N. Korotkov correctly note that the pressing task for the railroads is a radical technical improvement of their weighing equipment. Special attention should be paid to the elimination of important defects still existing in this sphere. It is necessary to speed up the supply to stations and sidings of car weighbridges for weighing cars of 93-ton capacity. The mass production of 150-ton weighbridges and their supply to the railroads should be speeded up. The weighing equipment manufacturing plants and scientific research organizations should intensify their work in improving car weighbridges and automatizing weighing, and the Ministry of Railroads of the USSR should actively participate in this work.

It is necessary to introduce improved measuring equipment methods to the railroads on a wider scale.

The quality of the scale repairs should be improved; repair work should be mechanized at a quicker rate and its cost reduced.

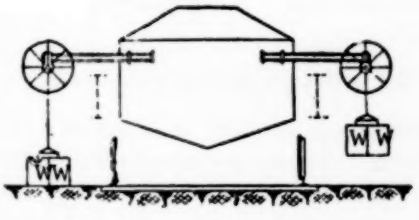
The training of gravimetric workers should be improved, especially since only a few engineers and technicians work in this sphere of railroading.

Weighing equipment is an important part of the railroad system and should be the subject of constant attention and care on the part of the Ministry of Railroads of the USSR.

A RATIONALIZED METHOD OF CHECKING SCALE CARS

E. E. Zaslavskii

Scale cars used in blast furnace shops of metallurgical plants consist of a hopper which rests on a system of levers mounted on a trolley.



Scale cars are usually covered for checking with a deck which is loaded with 250 standard weights of 20 kg each. The weights are placed in turn over each of the knife-edge bearings (checking "at corners") and then over the middle of the hopper. Some plants, instead of the 20 kg weights, use 500 kg and 1000 kg weights, which are loaded by means of a crane into the hopper.

In either case a reliable check of the gear-ratio equality of all the four weight-bearing levers is not provided, since it is impossible to sufficiently concentrate the weight over only one of the knife-edge bearings, and part of the load is taken up by the other bearings.

Checking the scales by means of the 20 kg weights also requires a large expenditure of labor and time (a crew of six men carries out the checking in 8 working hours).

The author of this article has introduced a rational method of checking the scales. Four sockets are made in the sides of the hopper above each of the knife-edge bearings, in order to hold H-beams which are secured in them for testing and protrude horizontally on both sides of the hopper (see figure). A winch for lifting the standard weights is mounted at the end of each beam. In testing, the weights are lifted only a few centimeters off the ground.

For testing at the corners, two half-ton weights W are suspended from each beam in turn. In order to prevent the scales from turning over the loaded bearing, a small weight is placed in the hopper after the checking of the unloaded scales. The length of the console beams is chosen to make the loading of the knife-edge bearing equal 3 tons.

After the equality of the gear ratios of all the four weight-bearing levers has been checked, the scales are tested with a 4-ton load, applied simultaneously to all the four console beams.

This method has been successfully used for approximately two years and ensured an efficient operation of the scales. The checking does not require the expenditure of a large amount of labor or time.

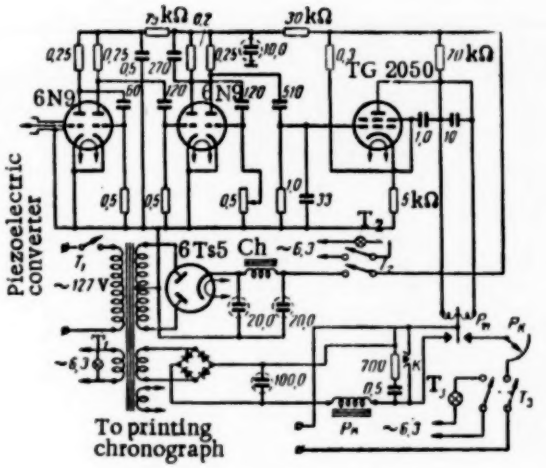
Editorial Note. When these scales are checked by the method suggested by the author of the article, the lever arm ratios should be accurately observed so that the same pressure is applied to each of the knife-edge bearings. In order to reduce checking errors, the scales should be loaded up to their maximum load, i.e., up to 15, 25, or 40 tons.

MEASUREMENTS OF TIME

AN INSTRUMENT FOR CHECKING CHRONOMETERS

A. I. Konstantinov

State control of chronometers at the All-Union Scientific Research Institute of the Committee of Standards, Measures, and Measuring Instruments is at present carried out according to the vernier principle: the half-second strokes of a chronometer and standard time signal, which are transmitted at 60/61 sec intervals, are observed simultaneously on an oscilloscope and the instant of their coincidence recorded, i.e., the indications of the chronometer and the vernier signals for that instant are recorded. This method ensures an accuracy of a single comparison of ± 0.04 sec. For this comparison a standard signal generator, equivalent in accuracy to standard clocks or a receiver for the reception of radio time signals, is required. In the latter case the comparison of a large number of chronometers is difficult. Comparison by the vernier method requires concentrated attention of the observer and is not convenient for future use, since it is planned in the future to replace the vernier signals by signals transmitted once every second.



The suggested method of checking chronometers required a standard contact clock and a recording device with a tolerance of ± 0.01 sec. The chronometer balance strokes, produced every 0.5 sec, are transformed into electrical impulses by means of a piezoelectric converter, a differentiating circuit, amplifier, and an electromagnetic relay. The electrical impulses from the chronometer and the clock are recorded by a digital printing chronograph.

The correction of the chronometer by means of the standard clock is obtained from the formula:

$$U=(T_{cl}-T_{ch})+(t_{ch}-t_{cl}),$$

where T_{cl} and t_{cl} are the readings of the clock and the printing chronograph at the instant of a standard clock impulse; T_{ch} and t_{ch} are the readings of the chronometer and the printing chronograph at the instant of a chronometer impulse.

The impulses from the chronometer occur every 0.5 sec, and from the clock every 30 sec. It is very difficult to identify the indications of the chronograph with those of the chronometer dial. This difficulty is overcome by selecting electromechanically every 15th pulse of the chronometer, thus making the impulses follow every 7.5 sec and making them easily related to the chronometer dial readings.

The circuit of the instrument for the conversion of the chronometer balance strokes into electrial impulses is shown in the figure.

The piezoelectric converter is placed on the chronometer cover glass, and its impulses are fed to the grid of the first tube of a four stage RC coupled amplifier; the amplified and differentiated impulses trigger a thyratron, whose anode circuit contains the winding of a polarized relay P_n. The polarized relay operates a step-by-step switch P_k which selects every 15th impulse and transmits impulses to a recording instrument if the step-by-step selector contact circuit is closed.

Chronometer impulse recordings should be carried out during one minute: the first recording at the beginning of the minute, the last one at the end of the minute, in all 9 recordings. Seconds are taken from the first recording, tenths and hundredths of a second as the mean of the 9 recordings; all the 9 recordings of tenths and hundredths of a second are, as a rule, the same.

The phasing of the selected impulse with the beginning of the minute on the dial of the chronometer is attained by means of a correct switching in of the anode voltage with tumbler switch T_2, or by means of push button K, which stops the sending of impulses from the chronometer or provides additional impulses to the step-by-step selector. It is, however, possible to omit the phasing altogether, by taking the chronometer dial reading at the time of an impulse. In the interval between the impulses, those of the clock are also recorded; if the clock impulses are superposed on those of the chronometer, the clock is recorded before or after the recording of the chronometer impulses.

The checking of chronometers by these means lasts some 2-3 minutes and does not require any concentration by the observer. The error in determining the correction for a chronometer does not exceed ± 0.002 sec when a recording chronograph of the "Etalon" plant is used. This method of checking requires a considerably smaller experience on the part of the observer than the vernier signal method. The method also provides the possibility of checking chronometers placed inside thermostats for determining the effect of temperature on their operation, and studying dispersion of the half-second strokes of the chronometer balance. This method of testing chronometers has passed its tests at the time service department of the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements (VNIIFTRI) with satisfactory results.

MECHANICAL MEASUREMENTS

A THERMODYNAMIC SCALE FOR HIGH PRESSURES UP TO 25,000 kg/cm²

M. K. Zhokhovskii, V. N. Razuminkhin, E. V. Zolotykh, and L. L. Burova

Dealt with in [1] are investigations of the melting curve of mercury up to 20,000 kg/cm² with reference to the problem of establishing a high pressure scale, confirming experimentally the permissibility of extrapolating the melting point equation of mercury (which is taken as the basis of the thermodynamic scale of pressures)

$$\lg(P+37663)=1.21458\ \lg T+1.69765 \qquad (1)$$

up to 20,000 kg/cm² with an accuracy of the order of 0.4–0.8%. The present work deals with new investigations in an enlarged range up to 25,000 kg/cm².

Manometer used	Temperature, K°	Pressure kg/cm² from tests with a manganin manometer, P_e	Pressure kg/cm² calculated from Eq. (1) of the melting point curve P_c	$\frac{P_c-P_e}{P_c}$ %	Manometer used	Temperature, K°	Pressure, kg/cm² from tests with a manganin manometer, P_e	Pressure, kg/cm² calculated from Eq. (1) of the melting point curve P_c	$\frac{P_c-P_e}{P_c}$ %
2	273.16	7638	7719	+0.4	1	311.43	15527	15552	+0.15
2	273.16	7725	7719	−0.1	2	311.69	15611	15607	−0.05
2	279.49	8989	8999	+0.1	2	313.31	15933	15942	+0.05
1	283.20	9745	9751	+0.05	2	313.39	15975	15960	−0.1
2	283.22	9745	9756	+0.1	4	313.74	16038	16032	−0.05
1	283.22	9746	9756	+0.1	2	316.42	16595	16531	0.0
4	284.31	9968	9977	+0.1	2	318.28	16997	16977	−0.1
5	284.46	9983	10008	+0.25	5	320.97	17562	17533	−0.15
7	284.46	10005	10008	+0.05	7	320.97	17559	17538	−0.1
2	285.23	10155	10166	+0.1	3	321.33	17550	17613	+0.35
1	288.11	10729	10746	+0.15	2	321.40	17617	17628	−0.1
1	288.18	10743	10766	+0.2	3	321.54	17554	17638	+0.6
2	288.22	10734	10772	+0.35	4	323.64	18086	18037	+0.05
2	290.28	11165	11196	+0.3	2	323.85	18173	18141	−0.2
2	293.38	11804	11829	+0.25	3	326.43	18533	18591	+0.55
4	294.27	11993	12015	+0.2	2	328.41	19225	19179	−0.25
2	295.45	12165	12256	+0.75	3	330.86	19434	19611	+0.6
1	295.53	12267	12270	+0.05	4	332.85	20082	20010	−0.25
5	296.53	12495	12486	−0.05	2	332.92	20095	20044	−0.25
7	296.58	12500	12486	−0.1	5	333.03	20119	20067	−0.25
5	296.60	12495	12490	−0.05	7	333.03	20101	20067	−0.15
7	296.60	12500	12490	−0.1	2	334.23	20359	20323	−0.2
2	298.30	12838	12839	0.0	2	336.58	20917	20817	−0.5
2	301.34	13466	13466	0.0	2	337.63	21113	21045	−0.3
2	303.35	13858	13879	+0.15	5	340.11	21616	21563	−0.25
4	303.96	14017	14006	−0.1	7	340.11	21580	21563	−0.1
4	304.24	14029	14064	+0.25	2	342.46	22149	22060	−0.4
2	306.83	14567	14600	+0.2	2	346.97	23117	23015	−0.45
1	306.97	14631	14628	0.0	5	347.21	23102	23062	−0.15
2	308.31	14846	14905	+0.4	7	347.21	23153	23062	−0.4
5	308.80	15015	15008	−0.05	2	351.98	24187	24082	−0.45
7	308.80	15009	15003	0.0	5	354.79	24731	24678	−0.2

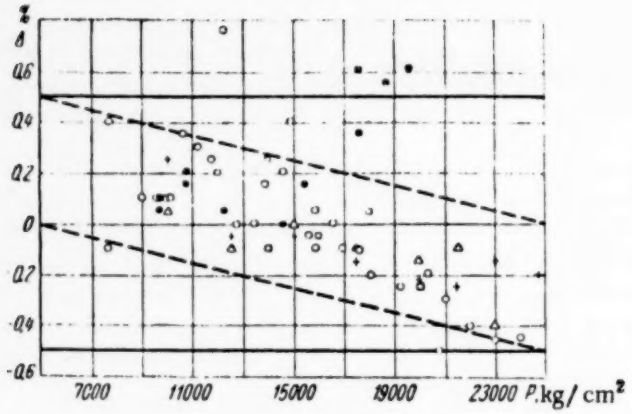


Fig. 1 Relative differences $\Delta = \frac{P_c - P_e}{P_c}$ in percentages plotted against pressure. Notation: points – manometer No. 1; circles – manometer No. 2; crosses and circles – manometer No. 3; squares – manometer No. 4; crosses – manometer No. 5; triangles – manometer No. 7.

As in previous experiments, temperatures were measured in both directions at the solidification and melting points with several determinations of each temperature. Tests showed that the direction of the process has no systematic effect on the value of the measured pressure. The differences discovered were negligibly small and of a random nature.

For measuring balanced pressures one of the former manganin manometers No. 2 was used, as well as three new instruments Nos. 4, 5, and 7. In this experiment, manometer No. 2 was used in the range of 20,000-24,000 kg/cm², manometer No. 4 between 10,000 and 20,000 kg/cm², and manometers Nos. 5 and 7 between 10,000 and 24,700 kg/cm². The last two manometers were used simultaneously, i.e., in the series of experiments in the above range the two manometers measured the same balanced pressure at the same time.

As in previous experiments, the resistance manometers were carefully checked by means of a piston manometer with an extended range of measurement. In previous experiments a piston manometer which measured up to 10,000 kg/cm² was used; this time a newly made manometer with a range up to 15,000 kg/cm² was employed. The extension of the upper calibration limit up to 15,000 kg/cm², even with the range of experiments raised to 25,000 kg/cm², lowered the relative extrapolation range from a ratio of 2 to 1.7. Later, it will be shown that this had a beneficial effect on the test results, although the melting point curve (1) was extrapolated up to 25,000 kg/cm².

Calibration of both the new and old coils confirmed the nonlinearity of the relation between the resistance of manganin manometers and pressure

$$P = P_0 + A\Delta R + B(\Delta R)^2, \qquad (2)$$

where P_0, A, and B are constants determined for each coil from experimental data.

The pressure calculated from (2) for all the coils did not differ from the experimentally obtained values by more than 0.05% at pressures P > 3000 kg/cm². For smaller pressures of no interest in this work the deviations were a little larger.

Repeated calibrations also provided a measure of the consistency of readings of various coils. Variations of the manganin manometer readings, evaluated as maximum deviations from a mean value for each coil, did not exceed, at pressures above 5000 kg/cm², the value of 0.1-0.3%. Slightly worse results were obtained for the old manometer No. 3. For this reason, neither this manometer nor coil No. 1, which went out of action, were used in the experiments.

New calibrations for manometers Nos. 2 and 3 up to 15,000 kg/cm² were carried out soon after the previous experiments [1]. Moreover, a slightly different equation P = f(ΔR) was obtained, thus providing a more accurate estimation of the balance pressures.

A comparison of the old and new calibrations obtained for manometers Nos. 2 and 3 shows that the effect of leakage of liquid in the previous experiments was not as pronounced as could be expected. The value of the previously discovered discrepancies of 0.4-0.8% was mainly due to the wider extrapolation range.

The table contains all the final results of the new experiments and also data from [1] including the corrected values of manometers Nos. 2 and 3. Thus measurement results of six manganin manometers are listed. The table indicates the manometer used, the values of the balance temperatures and pressures P_e, measured directly by a

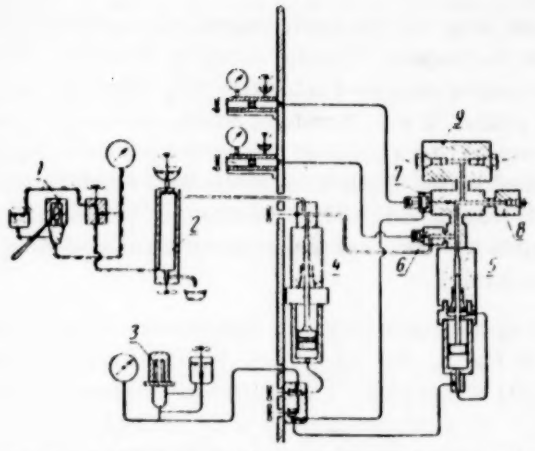


Fig. 2. Schematic of the equipment for comparing resistance manometers at pressures up to 25,000 kg/cm².

thermocouple and by a manganin manometer, values of pressures P_c, calculated from Eq. (1) of the melting point curve, and finally, the differences $\Delta = \frac{P_c - P_e}{P_c}$ expressed in percentages.

Curves of Fig. 1 show in a more graphic manner the deviations of difference Δ along the melting point curve. Let us first of all note that practically all the experimental points lie within the region of ± 0.5% over the whole pressure range of 7500-25,000 kg/cm². Only four points out of 64 slightly exceed these limits, moreover, three of these points were obtained on manometer No. 3, which, as it was mentioned above, has the worst measurement stability. The overwhelming majority of deviations of the remaining experiments falls within the limits of ± 0.3% to 0.35%. Although, according to the table, the deviations are random both in sign and magnitude, it is possible to discern from Fig. 1 a certain systematic trend in their characteristics with respect to pressure. The overwhelming majority of the observed deviations fall within a slanting area, shown in Fig. 1 by dotted boundary lines. In the initial section of the area the Δ deviations are mainly positive; next, negative deviations begin to predominate. This phenomenon is probably related to systematic errors made in extrapolating the melting point curve and the empirical formulas of the manganin manometer.

Thus, the data given above, based on a large number of experiments with various manganin manometers, provide good reason to assert that the thermodynamic scale for high pressures, represented by Eq. (1) of the mercury melting point curve, is reliable within ± 0.5% in the range up to 25,000 kg/cm².

This error is the sum of the errors of extrapolation and errors due to the variations of the manganin manometer readings. With the above method and range of extrapolation the reliability of ± 0.5% approaches, it would appear, its limit. Greater accuracy can be obtained by means of other methods (examined in [2] and [3]).

The thermodynamic scale is based on Simon's equation (1) in the form he suggested originally with three empirical constants:

$$\lg(a+P) = c \lg T + b. \tag{1'}$$

The better-known Simon's equation contains two constants only and has the form:

$$\frac{a+P}{a} = \left(\frac{T}{T_0}\right)^c. \tag{3}$$

The author of [3] discovered very interesting trends in the melting process of substances under pressure. On the basis of these regular trends it was possible to discover the physical meaning of constants a and c in Simon's equation (3), to derive their analytical expression in terms of melting parameters, and to represent (3) in the form:

$$\frac{cP + \frac{\lambda_0}{\Delta v_0}}{\frac{\lambda_0}{\Delta v_0}} = \left(\frac{T}{T_0}\right)^c, \tag{4}$$

where λ_0, Δv_0 and T_0 are, respectively, the melting heat, change in volume, and melting temperature at atmospheric pressure; c is the former constant.

Theoretically, it is now possible to represent the mercury melting point Eq. (1) in the form of (4), but precise experimental data for determining the new constant $\lambda_0/\Delta v_0$ are lacking. A simple recalculation of constants from

the empirical data of the mercury melting point curve would not provide any new information. For this reason we continued to use Eq. (1) for the first approximation of the pressure scale.

On the basis of the mercury melting point equation (1), and using the previously constructed equipment, it was not difficult to produce pressures up to 25,000 kg/cm^2. For the purpose of routine checking, however (for instance, for the calibration and checking of manometers), this method requires a relatively long time, similar to that used in calibrating thermometers by means of reference points. It was, therefore, decided to use the manganin manometers, employed in the present investigation, for constructing a group of reference instruments which in practice represent the newly established thermodynamic pressure scale. These instruments were carefully investigated by means of a piston manometer up to a pressure of 15,000 kg/cm^2 and, in addition, they were calibrated at points of the thermodynamic scale up to a pressure of 25,000 kg/cm^2. For further use of these manometers as reference instruments it was necessary to compare them to each other.

For this purpose and for subsequent calibrations and checking of various technical high pressure instruments a special equipment was constructed whose schematic is shown in Fig. 2. The equipment consists of the following basic units: hand pump 1 with a liquid separator 2, a mechanically driven pump 3, a preliminary pressure multiplier 4 attaining pressures up to 6000 kg/cm^2, main multiplier 5 attaining pressures up to 25,000 kg/cm^2, preliminary pressure valve 6, a 25,000 kg/cm^2 pressure valve 7, and reference manganin manometers 8 and 9 being compared. For calibration or checking purposes one of these manometers can be replaced by any commercial instrument.

By means of pump 1 the high pressure system is filled with benzine and a preliminary pressure of the order of 1000 kg/cm^2 is established, which is then raised to 4500-5000 kg/cm^2 by multiplier 4 which is fed from pump 3. Next valve 6 is closed and a further increase in pressure is attained by means of muliplier 5 and pump 3. When the required pressure is reached, the manganin manometers are disconnected from multiplier 5 by means of valve 7, thus preventing the possibility of the pressure dropping.

By means of this equipment a comparison was made of manganin manometers No. 2, 3, 4, 5, 7, and the new instrument No. 6 in various combinations up to a pressure of 5000-25,000 kg/cm^2. Readings obtained for each manometer from empirical formulas were also compared.

The results of these comparisons show that differences in the readings of coil pairs decrease with increasing pressure. Maximum differences were registered at pressures of 5000 kg/cm^2 and amounted to ±0.4%, whereas at pressures of 10,000 kg/cm^2 and higher, the difference did not exceed ± 0.2% and in the majority of cases were equal to ±0.1%. Substantially different results were obtained for the coil of manometer No. 3. Reading differences for that coil attained 0.7-1.5%. Thus, the unsatisfactory properties of this coil were confirmed once again, and the coil had to be excluded from the group of standard instruments. The data given above for the mutual comparison of the remaining manometers, up to a pressure of 25,000 kg/cm^2, show that the properties of the resistance manometers do not add any additional errors to those noted when their readings were compared with the thermodynamic scale.

These tests have also confirmed the expediency of extrapolating the manometer equations and the stability of their readings up to 25,000 kg/cm^2. Thus, each manometer of the above group reproduces the thermodynamic scale with a reliability of not less than ± 0.5%, and the constructed equipment provides the possibility of checking various instruments by the usual comparison method.

RESULTS

The thermodynamic pressure scale based on the mercury melting-point curve equation was extended to 25,000 kg/cm^2 with a reliability of ± 0.5%. A group of reference resistance manometers was established which reproduce in stated limits, with the above reliability, the thermodynamic pressure scale. An apparatus was constructed by means of which the pressure scale values can be used for calibrating any high-pressure commercial instrument.

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NEW S-SHAPED SPRINGS FOR MANOMETRIC INSTRUMENTS

I. A. Sychev

Diaphragms, bellows, torsion tubes, and tubular springs are widely used as elastic sensitive elements for instruments and automatic equipment in mechanical remote control and for registration of various parameters of technological processes. Tubular manometric springs have been used in industry for more than 100 years.

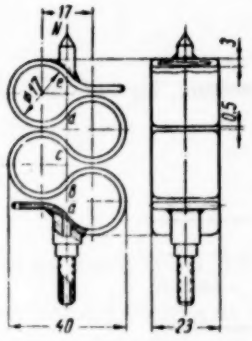

Fig. 1. Construction of a four-turn S-shaped tubular spring.

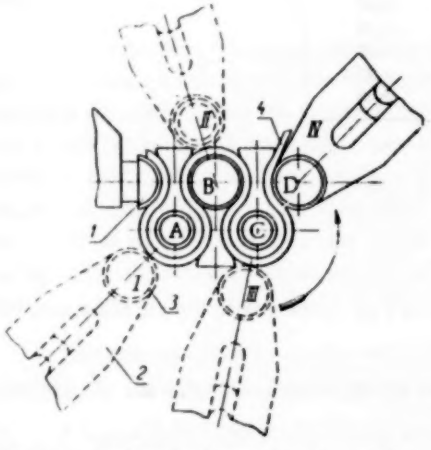

Fig. 2. Winding schematic of an S-shaped tubular spring. A, B, C, and D) mountings; 1) Support; 2) moving lever with roller 3; 4) sealed end of the manometric tube; I, II, III, and IV) Position of lever 2 at different instants of spring winding.

Under the effect of internal pressure the cross section of a tubular spring is strained and its area increased, approaching that of a circle and tending to unwind the tube. Thus, by means of tubular springs, pressure is transformed into a movement of the free end of the spring and transmitted to the mechanism of an instrument or any other device.

There are many types of tubular springs: single turn, multiturn, helical and spiral shaped, screw type, and others. The displacement of the free end of all these springs follows an arc.

The Scientific Research Institute of Thermal Instruments (NIIT) developed a new type of tubular manometric spring, the so-called S-shaped tube. The basic information on S-shaped springs, designed for manometric instruments, is contained in the trade specification NMP9-55-51. These springs have been successfully used in several thermal instruments developed by the Institute.

The S-shaped spring consists of an even number of series-connected single-turn tubular springs ab, bc, cd, and de (Fig. 1). When pressure is changed in an S-shaped spring, the displacements of the free ends of two adjacent springs are equal in size and directed at the same angle, but opposite in sign with respect to the central axis of the spring.

This results in a linear instead of a circular movement of the free end of the S-shaped tubular spring along the central axis of the spring, i.e., in a movement similar to that of bellows, diaphragms, and diaphragm boxes. Thus, conditions for a more effective unification of bellows, diaphragm, and spring instruments are created.

Tubular S-shaped springs are especially useful for measuring pressures above 16-20 kg-wt/cm^2, i.e., when bellows or diaphragms are difficult to use or cannot be used, owing to their low resistance, considerable stiffness, low stability, and unsatisfactory travel and hysteresis characteristics.

S-shaped springs are small, shock resistant, and highly efficient.

The NIIT has developed the technology for manufacturing the S-shaped springs and determined the type of heat treatment. Fig. 2 shows the device used for winding the springs.

The basic parameters of the springs were determined experimentally.

The spring was stretched by applying a force to its end N and the displacement was measured; thus, its stiffness was determined:

TABLE 1

Wall thickness, mm	Sensitivity ϵ, mm/kg-wt/cm^2	Stiffness c, kg-wt/mm
0,15	0,260	0,49
0,2	0,243	0,65
0,3	0,210	1,15
0,4	0,176	1,70
0,5	0,144	2,25
0,6	0,110	2,90
0,7	0,080	3,60
0,8	0,060	4,55
0,9	0,044	5,95
1,0	0,032	7,65
1,1	0,022	9,50
1,2	0,014	11,9
1,3	0,009	14,15
1,4	0,005	16,00

$$c = \frac{P}{\delta},$$

where P is the load, kg-wt; δ is the displacement, mm.

The sensitivity of springs was determined by raising the pressure inside them, measuring the displacement of their end N (see Fig. 1), and calculating it from formula:

$$\epsilon = \frac{\delta}{p},$$

where p is the pressure, kg-wt/cm^2.

TABLE 2

Several top measuring limits of manometers, kg-wt/cm^2	Wall thickness h, mm		
	λ_p=1.5 mm	λ_p=3 mm	λ_p=3.5 mm
6	0,18	—	—
10	0,48	0,10*	—
16	0,63	0,34	0,33
25	0,80	0,56	0,52
40	0,95	0,73	0,68
60	1,07	0,86	0,82
100	1,18	1,02	0,97
160	1,27	1,13	1,12
250	1,35	1,23	1,20
300	—	1,27	1,25
400	—	1,33	1,28

* Wall thickness is given for a working travel of λ_p = = 2,73 mm.

Tests were made with an S-shaped spring of the dimensions shown in Fig. 1, and made out of alloy steel brand 30KhGSA.

Test results for determining the sensitivity and stiffness of S-shaped springs with respect to the thickness of their walls are shown in Table 1.

Knowing the stiffness of the spring it is possible to determine the permissible load on the spring exerted by the instrument mechanism. Knowing the sensitivity ϵ it is possible to calculate the thickness of the walls required for various measuring ranges and a given displacement λ_p of the end of the spring (Table 2).

These experimental data hold for the spring shown in Fig. 1. It is, of course, possible, by changing the spring dimensions and the material it is made of, to raise its sensitivity.

The top pressure limits for a given working travel can be raised by changing the relations of the spring axes, especially by increasing the minor cross-sectional axis.

The limit of proportionality of the tested S-shaped springs corresponds to a displacement of the end N (deflection) of 5-6 mm. The nonlinearity of the S-shaped springs' free end displacement is in the limits of 0.5-1.5% and its hysteresis does not exceed 1% of the maximum working travel.

It is known that the spring pressure gages, vacuum gages, and vacuum pressure gages are similar in the principle of their operation and in their construction to manometric vapor, gas, and liquid thermometers.

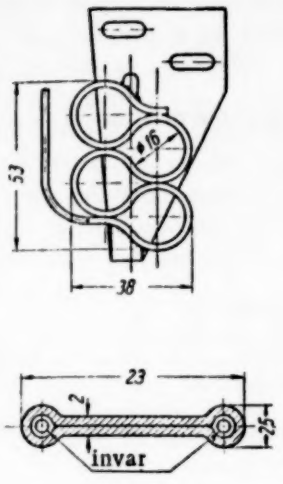

Fig. 3

The use of similar springs in these instruments makes it possible to unify their construction. For instance, these instruments can have the same basic construction, and the gas, liquid, or vapor thermal system of manometric thermometers with a single turn tubular shape can be replaced by a tubular spring unit of a pressure gage, a vacuum gage, or a vacuum pressure gage (with an appropriate recalibration of the scale). S-shaped tubular springs have also made it possible to unify completely bellows and spring instruments, including spring and bellows pressure gages and liquid manometric thermometers. The use of S-shaped springs in liquid thermometers is much more advantageous than that of bellows, since S-shaped springs have a smaller internal volume and provide a smaller temperature error due to changes in the temperature of the air surrounding the elastic sensitive element and the capillary tube of liquid thermometers. With small internal volumes it is possible to ensure an optimum relation between the initial internal volume of the spring and the increment to that volume at the working travel of the spring [1]. A large decrease in the temperature errors of liquid manometric thermometers is also due to the use of S-shaped tubular springs with cross sections of a new shape (Fig. 3) [2].

Figure 3 shows an S-shaped spring which is used in manometric thermometers. For a working travel of 3 ± 0.25 mm it has an internal volume increment of 0.43 cm^3.

The initial internal volume of the spring is very small, amounting to something of the order of 0.12-0.15 cm^3. The pressure which produces the working travel of the spring amounts to 80 ± 10 kg-wt/cm^2. The stiffness of the spring is 7 ± 0.5 kg-wt/mm. Its elasticity limit corresponds to its travel of 6.5-7.5 mm.

The distinctive feature of a manometric tube with a new cross-sectional shape is its middle squeezed-in portion without a gap between the two walls. A gap between them is formed when the pressure of the filling liquid rises.

Two channels with drop-like cross-sectional shapes are placed symmetrically at each side of the squeezed-in portion; these channels increase the strength of the tube and provide an even distribution of the liquid in the gap between the walls along the whole length of the tube. An increase in the larger cross-sectional axis of the tube due to the widening of the middle squeezed-in section produces, for the same remaining conditions, a larger increment in the volume of the spring when extended to its working travel. At the same time the initial internal volume of the spring remains the same. Thus, the spring with the internal cross section of a new shape provides an optimum relation between the initial internal volume of the spring and the increment to this volume when the spring is in its extended travel position. The efficiency of the spring is also considerably increased at the same time.

The manufacture of springs with a new cross-sectional shape is simpler and more economical, since in winding the manometric tube it is not necessary to use any fillers such as salt, sand, or low-temperature alloys.

A lowering of the temperature error due to a rise in the volume of liquid thermometers' liquid is achieved by placing in the spring channels an invar wire with a cross section calculated to compensate either completely or partially for the increase in the volume of liquid by increasing the annular space between the wire and the channel sides.

The use of tubes with a cross section of the new shape in gas and vapor thermometers tends to lower their temperature errors and decrease the size of the vapor thermometer temperature bulbs.

In the author's opinion, the metrological and mechanical properties of the S-shaped springs can be considerably improved if precision tubes and dispersion-solidified alloys are used, such as ÉI-702 according to ChMTU 5834-57, beryllium bronze brand BrBNT, and others, which when hardened possess the required plastic properties and acquire the high mechanical elastic properties after heat treatment at the optimum temperature for 2-3 hours with subsequent gradual cooling.

Such a process of "improving" metals leads to the preservation of the shape and size initially given to the spring or to their formation during heat-treatment by means of special equipment. Another no less important characteristic of dispersion-solidified alloys is the possibility of their heat-treatment in vacuum ovens. The lack

of commercial production of tubes from dispersion-solidified alloys is a serious obstacle in the development and perfection of tubular springs and hence of instruments in which they are used.

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A PORTABLE PRESS FOR CHECKING MANOMETERS

S. F. Yakubov

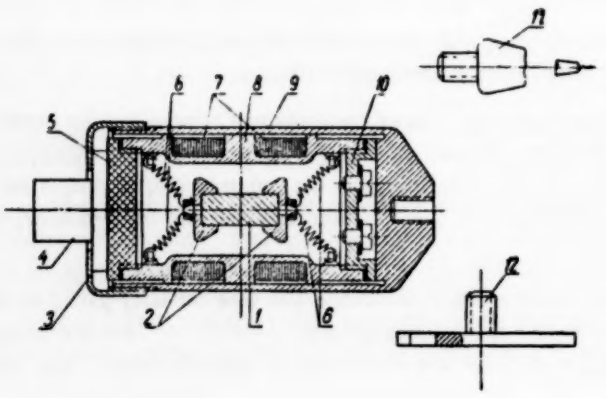
In order to improve the portable press for checking manometers, it is suggested that the press, the racks, and the oil tank, be mounted on a textolite base of 450 × 280 × 20 mm, which can be enclosed by a cover with a handle.

In order to raise productivity, the press is supplied with five instead of two test racks, which have connecting pipes and valves, thus providing for the testing of over 100 instruments in 8 hours. Additional racks provide the possibility of testing pressure-vacuum gages without disconnecting the reference instruments (a pressure and a vacuum gage). Places can be provided in the instrument cover for the transportation of reference instruments.

A SEISMIC VIBRATOR TRANSDUCER WITH HELICAL SPRINGS

L. D. Gik

In the overwhelming majority of known designs of seismic vibration transducers used for measuring vibrations, the elastic element consists of a system of two flat parallel springs of some shape or other. It is sought in their design to attain the required stiffness in the direction of the measurement (perpendicular to the plane of the springs) and the largest possible stiffness in the transverse direction. However, even in the best constructions of this type for a seismic frequency of 10 cps it is normally impossible to raise the measuring frequency range above ~150 cps, since the system becomes unstable to transverse vibrations [1]. It should also be noted that the springs must be made very carefully, choosing by experiment their best shape, thus complicating construction and adjustment of the transducer, especially under conditions of single article production. In cases when the orientation of the transducer is arbitrary, and it is impossible to compensate for the bending of the spring under the weight of the seismic mass, the frequency range of measurement becomes even more restricted.



It is interesting to find another solution of this problem in which the elastic element has

approximately the same stiffness both in the measurement and transverse directions. In order to make the transducer insensitive under these conditions to transverse vibrations, it is necessary to fulfill two conditions: when the mass is moving in the transverse direction, no signal must be produced in the electromagnetic system of the transducer (obviously, with the appropriate degree of accuracy), and the movement of the transducer body in the transverse direction must reproduce any displacement of the seismic mass in the measurement direction. The first condition places certain requirements on the construction of the transducer electromagnetic system; in the induction system this condition will be fulfilled if the magnetic field is perpendicular to the axis of measurement. The second condition requires an appropriate construction of the elastic elements. Thus, this condition will be fulfilled if, for instance, the mass is symmetrically fixed by several helical springs (for instance, three or four springs at each end of the seismic system).

With such a construction it is necessary to use liquid damping, since it is necessary to eliminate resonance not only in the axial but also in the transverse direction.

The figure shows an induction type transducer with a moving magnet developed by the author.

The cylindrical permanent magnet 1 and pole piece 2 pressed onto it form the seismic mass, which is fixed to the duralumin former 8 of coils 7 by means of eight helical springs 6 (four at each end). Former 8 serves at the same time as a vessel for the silicoorganic damping liquid; the vessel is closed at its ends by means of screw-on lids 5 and 10. Stem 4 is fixed to the lid 5. The whole system is placed in a casing 9 which also serves as a magnetic core and screen. The transducer is secured by a cover 3 screwed onto the casing.

The transducer can be operated as a portable one (with one of the exchangeable end-pieces 11 fitted to it) or for stationary operation (with flange 12 fixed, instead of the end-piece, for mounting on the object under investigation by means of a bolt through the holes cut in the flange).

The technical characteristics of the vibrator are: natural frequency of oscillations, about 11 cps (with liquid damping); natural frequency in the transverse direction, 13 cps; the damping is close to the critical ($\epsilon \approx 1$) at a temperature of 20°C; its frequency characteristic is horizontal up to ~400 cps; the error due to transverse vibration does not exceed 10%; the sensitivity is about 200 mv/mm/cps.

In conjunction with a correcting circuit this transducer was used for measuring vibrational displacements in thr range of 2-400 cps.

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MAGNETIC TAPE RECORDING OF OSCILLOGRAMS OF INFRASONIC PROCESSES

V. A. Nosov

Magnetic tape recording of oscillograms opens up new possibilities in the field of experimental work.

By using a magnetic tape whose ends are connected together to form a ring, a recording head and a delay device on the erasing head, it is possible to record, without the risk of missing them, phenomena of particular interest, such as the instant of the destruction of material through fatigue, seismic vibrations, etc.

The possibilities of recording continuously for many hours and of reusing the tape make for efficient and and convenient operation.

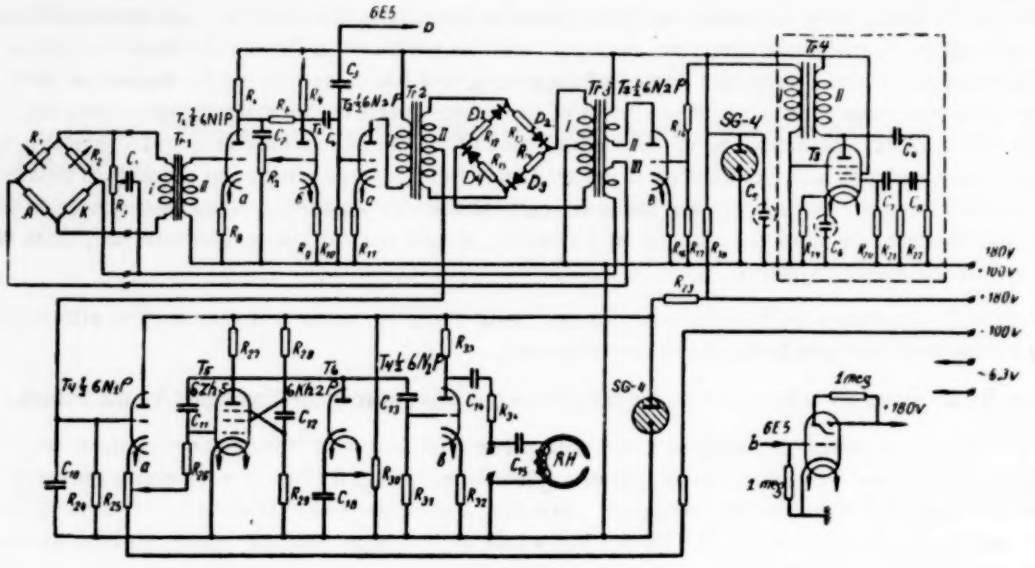

Fig. 1

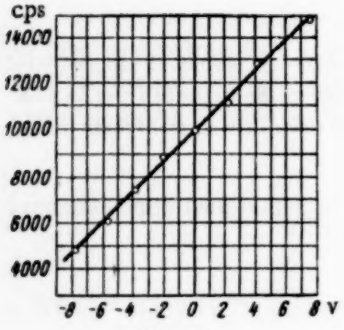

Fig. 2

This article deals with an apparatus which records static and dynamic processes in the operation of machines and mechanisms by means of wire, induction, or semiconductor transducers, and which was manufactured at the Ukrainian Scientific Research Institute of Mechanization and Electrification of Agriculture by the author of this article with the participation of V. A. Pavlenko, V. P. Zabotina, and V. I. Korol'kevich. The equipment works on the principle of frequency modulation and consists of four single-channel recording units, a tape propelling mechanism, and measuring bridges.

The measuring tension-sensitive bridge (Fig. 1) can consist of resistance wire transducers A and K or other transducers. The resistance elements of the bridge are balanced by means of slide wires R_1 and R_2, and the reactive elements by potentiometer R_3 and capacitance C_1.

From the measuring diagonal of the bridge the voltage is fed through transformer Tr1 to the grid of tube T_1 1/2 of 6N1P (a). The amplified signal passes through the coupling capacitor C_2 and voltage regulator R_7 to the second low frequency amplifying stage tube T_1 1/2 6N1P (b) which operates with an additional feedback voltage.

The anode circuit of tube T_1 ½ 6N1P(b) is connected through a coupling capacitor C_3 to an electronic indicating tube 6E5, which responds to the alternating component in the anode circuit and serves to balance the strain-sensitive bridge. A balance is indicated by the maximum expansion of the tube 6E5 luminous sector.

The output stage used tube T_2 ½ 6N2P with a negative current feedback. For detection, a ring phase-sensitive bridge is used, which consists of four diodes: D_1, D_2, D_3, and D_4, and resistors R_{12}, R_{13}, R_{14}, and R_{15}. One of the diagonals of the bridge is fed through transformer Tr2 by the voltage from the output amplifier stage. The other diagonal is fed with the modulating voltage of the reference oscillator through transformer Tr3 and buffer stage tube T_2 ½ 6N2P(b). The reference oscillator operates at f = 5000 cps in an RC connection and serves to feed the tension-sensitive and the phase-sensitive bridges. When the tension-sensitive bridge is balanced, the voltage at the output of the phase-sensitive bridge is zero. An unbalance of one or more of the tension-sensitive bridge arms leads to the appearance of a voltage at the ring phase-sensitive bridge. When the phase of the voltage at the measuring diagonal of the tension-sensitive bridge changes by 180°, the sign of the voltage at the ring phase-sensitive bridge is reversed. The output voltage of the phase-sensitive bridge is fed to the grid of the cathode follower tube T_4 ½ 6N1P (a). The cathode follower provides the required bias on the grid of the multi-

vibrator (T_5 6Zh5) so that its voltage is always slightly larger than the amplitude of the alternating component. The feeding of the integrating resistor R_{25} from a dc source provides a more accurate modulation and a wider controlled frequency range of the multivibrator (5-17 kc).

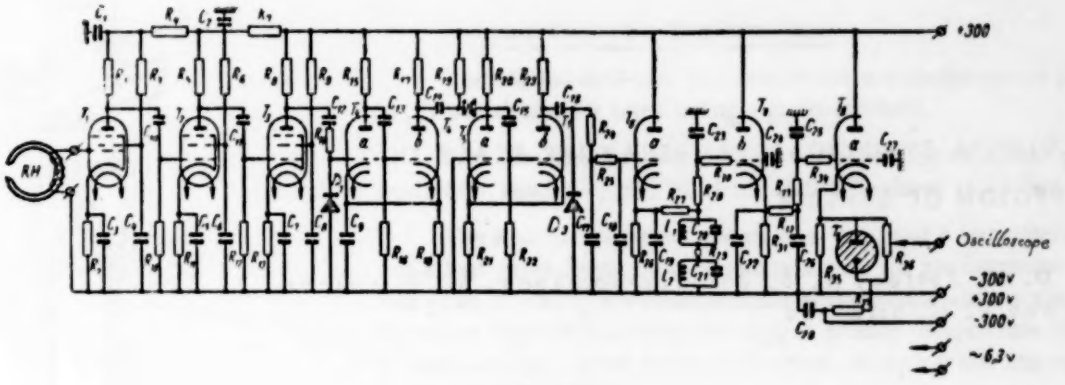

Fig. 3

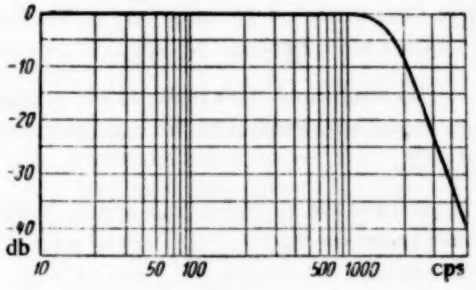

Fig. 4

Diode $T_6$6Kh2P is connected in the anode of the multivibrator in order to raise the steepness of the output voltage change which occurs when the input voltage exceeds a certain threshold value. As long as the voltage on the anode of the tube remains larger than that of the diode cathode, the latter shunts resistor R_{30}. Therefore, a sudden change in the voltage at the output of the circuit only occurs when the amplitude of the input pulse exceeds a value necessary to raise the anode current to a certain critical value. The use of the diode provides a clearly defined bend in the amplitude characteristic and a threshold of discrimination. The multivibrator frequency signals are supplied to the grid of tube T_4 1/2 6N1P (b) from whose anode the recording head is fed through a coupling circuit and a filter. The mean carrier frequency of the multivibrator is adjusted to 10 kc with deviations of ± 5 kc (Fig. 2). For a tape recording speed of 30 cm/sec this deviation provides recordings of signals up to 1.5 kc.

The reproduction of the magnetic tape recording is attained by inducing an emf in the playback head winding. This emf is amplified in three stages of an RC coupled amplifier consisting of tubes T_1, T_2, and T_3 (Fig. 3). The amplified signal is fed from the third stage through coupling capacitor C_{12} to tube T_4 (a), where the negative half cycles are cut off by diode D_1. The differentiated signal is amplified by the second half of triode T_4 (b). The negative going half-cycles are voltage limited by means of the crystal diode D_2 and then fed to controlled multivibrator T_5. Thus the series of positive going pulses is obtained at the anode of triode T_5, the intervals between pulse depending on the modulation. The triode operates in a minimum limiting condition. This condition provides in its anode circuit almost rectangular pulses of a strictly defined amplitude. The parameters of the circuit for measuring frequency are so chosen that capacitor C_{16} is completely charged by voltage pulses of the shortest duration in the anode circuit of the tube and completely discharged during the pulse intervals. When these pulses pass through the low-pass filter and a filtering tuned circuit (T_6 and T_7) the modulation is again restored and the signals are fed from the cathode follower (T_8) to the input of the cathode-ray tube. The overall frequency characteristic of the equipment is shown in Fig. 4.

It will be seen from the graph that the equipment provides a linear characteristic in reproducing observed processes up to 1500 cps, which is completely sufficient for investigating the work of machines and mechanisms.

THERMOTECHNICAL MEASUREMENTS

EVOLVING A PRACTICAL TEMPERATURE SCALE IN THE REGION OF 10-90°K

D. N. Astrov, A. S. Borovik-Romanov, M. P. Orlova, and P. G. Strelkov

Apparatus and Method of Measurement

Introduction. Owing to intensive work of physicists in the low temperature range, there was accumulated extensive data on thermometry, on the basis of which the Consultative Committee on Thermometry of the International Weights and Measures Bureau recommended in 1958 a temperature scale between 0.5 and 5°K for general use.

No resolutions were made or recommendations passed with respect to the scale between 5 and 90°K.

Individual Thermometer Characteristics

	IKh6	IKh6	IKh6	IKh6
R_0	104.906$_9$	105.105$_5$	104.075$_9$	108.817$_1$
R_{100}/R_0	1.39249$_0$	1.39251$_4$	1.392470	1.39252$_0$
R_{O_2}/R_0	0.243882$_2$	0.243886$_3$	0.243870	0.243886$_4$
R_{H_2}/R_0	0.004575$_7$	0.004551$_9$	0.004559$_0$	0.004573$_1$
δ	1.409	1.409	1.409	1.409

In 1954 the authors of this article published a short report on the establishment of a practical scale between the oxygen point and 10°K [1], on the basis of which the Principal Chamber of Measures and Measuring Instruments of the USSR made in the same year a proposal to the Consultative Committee to extend the international scale beyond its lower limit [2]. At the 1958 session of the Consultative Committee, the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements (VNIIFTRI) proposed organizing international comparisons of the existing scales between 90 and 10°K with that described in [1] in order to prepare the extension of the existing international scale down to 10°K.

The present article develops the propositions made in [1].

We determined the scale by means of a platinum resistance thermometer, since with respect to sensitivity and consistency of readings it matches perfectly the region between 90 and 20°K. Between 20 and 10°K the platinum thermometer has considerable defects, but as yet there are no better thermometers for this region.

It was shown in [3, 4, 5, and 6] that in the region under consideration the relation between temperature and platinum resistance cannot be represented analytically in a simple manner with a few constants. Therefore, the specification of a practical scale in the region of 90-10°K must differ from the one adopted in the International Temperature Scale.

Two versions for the specification of a practical scale can be suggested. The first method assumes the existence of a reference platinum thermometer or a group of thermometers, calibrated in degrees of the thermodynamic scale, and the transfer of these values from them by consecutive comparisons. In the second version the scale is based on a table which provides the relations between the relative resistance of certain grades of platinum and temperature, and also defines the standard method of referring the readings of individual thermometers to this table (the relation betweeen the temperature and resistance of these thermometers always differs to a certain extent from that given in the table). The correction referring the thermometer readings to the table should be represented by an analytical formula which connects the value of the correction to the thermometer resistance, measured at determined reference points. At present a satisfactory form of correction cannot be provided.

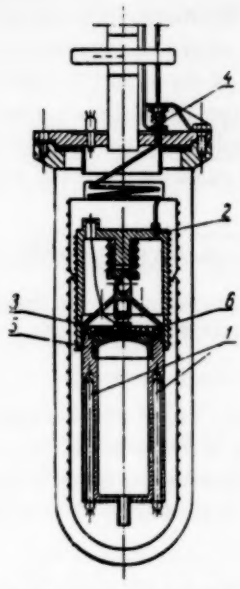

Fig. 1. Schematic of a gas thermometer mounting in a cryostat. 1) Platinum resistance thermometers; 2) capillary tube for filling with helium gas; 3) diaphragm; 4) valve; 5) thermometer body; 6) quartz disk.

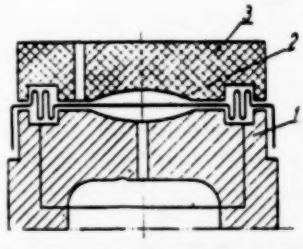

Fig. 2. 1) Thermometer body; 2) diaphragm; 3) quartz disk.

Both versions require the calibration of platinum thermometers by means of a gas thermometer, which is the basic instrument for reproducing the thermodynamic scale.

Platinum Resistance Thermometers

The one-hundred-ohm platinum resistance thermometer described in [7] was chosen for establishing a group standard.

Four such thermometers, which comprised the reference group, were made from spectrally pure platinum IONKh6 refined in a laboratory [8].

The stability of thermometers Nos. 2, 3, and 5 was observed for one and a half years during their comparison with the gas thermometer, and for four years following the establishment of the temperature scale. The thermometers were calibrated at the oxygen boiling temperature [9]. The root-mean-square errors in the calibrations of each thermometer amounted to $\pm$ (0.0015-0.0020)°K.

All the four thermometer scales were marked with the boiling point of hydrogen of natural composition [10]. The root-mean-square error of calibration amounted to $\pm$ (0.001-0.002)°K.

Gas Thermometer

Thermometer container without a dead space (Fig. 1). We used a gas thermometer without a dead space [11, 12], which has a considerable advantage in eliminating the largest manufacturing error. This advantage, however, can only be fully utilized with a sensitive and highly stable diaphragm which serves as the wall of the thermometer container and at the same time as the sensitive element of the volumetric manometer used for equalizing the pressure in the enclosed space of the container and the manometer system. The use of a diaphragm produces specific errors due to its finite sensitivity and to the possibility of spontaneous displacement of its balance positions as the result of repeated measurements of temperature between 300 and 10°K or sudden large variations in pressure overlooked by the experimenter.

In order to increase the stability of the balance position of the diaphragm it was corrugated at the sides (Fig. 2). So as to prevent deformations of the diaphragm by inevitable accidental large pressure variations, the deflection of a 36 mm diameter diaphragm was limited to 50 μ on each side by spherical surfaces of the required curvature and supplied with grooves to take the diaphragm corrugations.

Measuring device of the diaphragm manometer. The measuring device (Fig. 3), which equalizes the pressure in the thermometer container and its additional chamber, connected with the mercury manometer, remains the same as it was in [11, 12]. The diaphragm capacitor C_M is connected to one of the tuned circuits of the main audio frequency beat oscillator Q_1. Variations in the position of the diaphragm change the oscillator frequency. A rough indication of the diaphragm position is provided by a pointer instrument which reads the amplitude of the rectified voltage across the tuned circuit supplied from oscillator Q_1. The low Q tuned circuit provided all the measurements of the variations in the position of the diaphragm and hence, in the frequency of the oscillator on one side of the tuned circuit characteristic. Accurate adjustments were made by means of Lissajous figures on an oscilloscope, and a measuring oscillator Q_2, which provides frequency readings in the range of 3 cps.

In order to check the stability of oscillator Q_1, capacitor C_N was connected at intervals instead of the diaphragm capacitor.

The use of a gas thermometer without a dead space eliminated certain difficulties in measuring and the use of vaguely defined corrections, peculiar to the classical form of constant density thermometers, but introduced specific errors which attained at 90°K about $\pm 3.0 \cdot 10^{-3}$ and at 10°K about $\pm 2.0 \cdot 10^{-3}$°K.

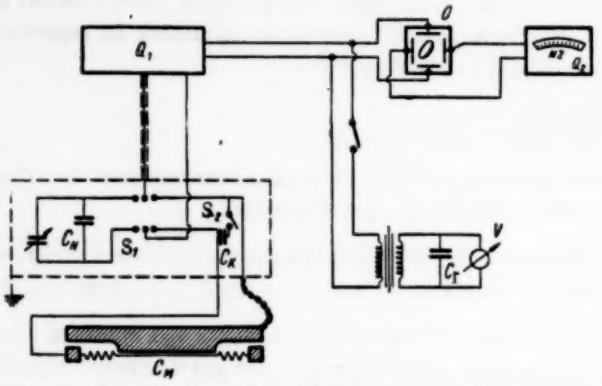

Fig. 3. Schematic of the diaphragm capacitor measuring circuit. S_1) changeover switch; S_2) switch for connecting additional capacity C_k used in measurements by the resonance curve method; O) oscillosope; C_r) resonance circuit capacitor; V) ac voltmeter.

Measurement of pressure in the gas thermometer container. When the diaphragm is balanced, the pressure in the thermometer container, within the limits of the above uncertainty, is equal to that of the container on the other side connected to the mercury manometer (with the accuracy of the Knudsen effect, which under the conditions of our measurements lies outside the limits of sensitivity).

The mercury manometer was described in [13].

The total error in determining the pressure can be evaluated in terms of temperature as $\pm 0.003_2$°K.

The method of selecting a pressure equal to the one in the container is shown in Fig. 4. A German silver tube 4 connects the valve cavity of the gas thermometer 1 to manometer A and the

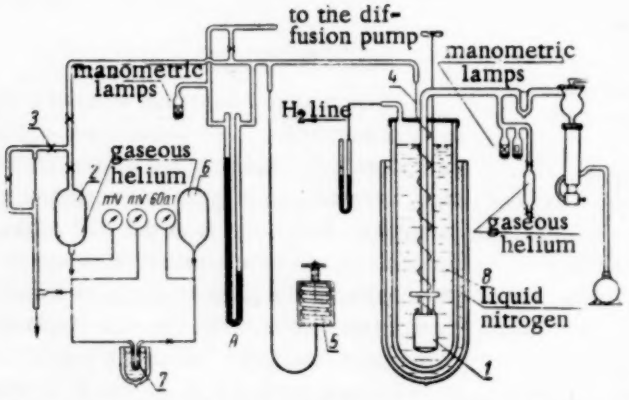

Fig. 4. General schematic of a gas thermometer with an adiabatic cryostat.

pressure control system, which provides evacuation and release of helium from flask 2 through the regulating valve 3. Accurate adjustment is made by means of bellows 5. Pressure is established by means of pure helium (less than $1 \cdot 10^{-5}$% of impurities), which is obtained by filtering commercial helium from flask 6 through a trap with activated carbon 7 at the temperature of liquid nitrogen. For calibrations at various temperatures, vat 8, filled with liquid nitrogen or hydrogen, is provided.

Assembly of the Equipment in a Thermostat

The gas thermometer (Fig. 1), together with the four platinum resistance thermometers 1, freely held in their sockets, is placed in a vacuum cryostat with an additional device for eliminating any heat exchange, similar to an adiabatic calorimeter [14]. Its lagging shields are supplied with heaters, whose temperature is kept equal to that of the thermometer unit by means of differential thermocouples; the shields carry all the leadout conductors and one turn of tube 2 is soldered to them and connects the cavity over diaphragm 3 to valve 4 in the cover of the cryostat, the valve being used for isolating the thermometer system from that of the pressure measurements. These precautions decreased the uncontrollable temperature drift to 0.0001 degree/minute.

Before final assembly, the gas thermometer container and the cavity above the diaphragm were connected by means of a pipe, evacuated several times by a diffusion pump, and filled with pure helium up to a pressure of 900 mm Hg at 90°K. Next valve 4 was closed, the gas thermometer heated to room temperature, the connecting pipe squeezed in two places, cut, and soldered.

Despite the considerable pressure at room temperature, there was no noticeable change during 6 months in the hermetic sealing of the container (changes $< 5 \cdot 10^{-3}$%).

Thermal contact between the unit and the resistance thermometers was provided by a thin layer of Ramsay's vacuum paste smeared on the thermometers. Each resistance thermometer lead, before being connected to the leadout conductors glued to the shields of the cryostat, was wound round the gas thermometer unit and stuck to it by a self-polymerizing adhesive. The heater which was similarly glued to the unit provided an easy change from one calibrating temperature to another.

The insulation between the leads was measured and found to be so high that any leakage between the circuits could not have affected the results.

Measurement Technique

Calibration between 10.7 and 25°K was made in vat 8 (Fig. 3), filled with hydrogen under reduced pressure; between 20 and 60°K in hydrogen boiling at atmospheric pressure; between 50 and 90°K in nitrogen under reduced pressure; and between 78 and 95°K in nitrogen under atmospheric pressure. The overlapping temperature intervals provided a means of verifying the absence of an effect on the results due to variations in the temperature drop between the gas thermometer and the surrounding media in different vats.

Measurements were made by two people. One of them measured the resistances and the other equalized the pressure in the mercury manometer system. On the basis of an automatic recording of the manometric temperature all the calculations were referred to the mercury density at 26°C, the temperature maintained by the thermoregulator.

The normal boiling temperature of oxygen as determined by the International Temperature Scale (−182.97°C)* was taken as the initial point for measuring temperature by means of the gas thermometer. As previously stated, the oxygen boiling point was marked on platinum thermometer scales. On the basis of the mean value of the oxygen temperature point for this group of thermometers, the reference pressure corresponding to this point and the "thermometer gas constant" T_{O_2} / P_{O_2}, which figure in design formulas, were determined with special care.

Finally, the value of $W_T = R_T / R_0$ in the range of 10-90°K at 107 temperatures for the four thermometers, and the corresponding thermodynamic temperatures by the gas thermometer, were determined.

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A SEMICONDUCTOR THERMOCRYOSTAT FOR CALIBRATION OF STANDARD THERMOMETERS

A. S. Dzyuba and P. B. Kantor

Calibration of standard thermometers in the temperature range from +20° to −20°C is attended with considerable difficulties because of the lack of convenient and dependable thermostats for this temperature range.

The production and automatic regulation of temperatures below +20°C requires the use of a cooling source, which considerably complicates the apparatus. Employment of freezing mixtures makes it possible to carry out calibration of thermometers within the indicated range, but it is attended by a very important shortcoming – the presence of considerable gradients in the temperature field of the mixture.

For reproduction of temperatures in the range only a little below room temperature, it is most promising to use semiconductor thermocouples as cold sources, because of their simplicity of construction and convenience of utilization [1].

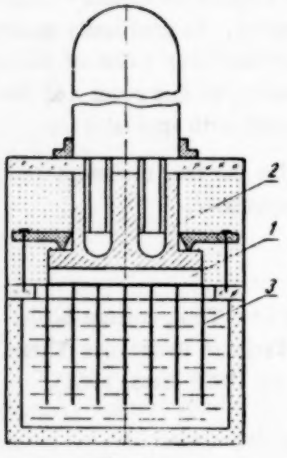

Fig. 1

In the thermocryostat developed at the Kharkov State Institute of Measures and Measuring Instruments for calibration of standard thermometers (Fig. 1), thermal batteries of semiconductor materials made by the Leningrad Sovnarkhoz (Leningrad Council of National Economy) were used for cooling purposes [1].

The cold junctions of thermoelectric battery 1 are in contact with aluminum block 2; the block is provided with boreholes in which the thermometers to be calibrated are inserted. To conduct the heat away from the hot thermocouple junctions, the radiator system 3, immersed in ice, is used as a heat sink.

The thermocryostat is contained in a steel cylinder closed at both ends by textolite covers. A massive copper radiator is affixed to the bottom cover and to it is clamped a laminated plastic plate which carries the thermoelectric battery and the aluminum block holding the thermometers. Electrical insulation of the thermo-battery, radiator, and aluminum block is achieved by mica spacers of 20-40 μ thickness moistened with mineral oil.

In order to decrease heat flow to the aluminum block, the plastic clamping plate is designed so that the contact area is a minimum.

Thin copper cylinders are pressed into the borehole channels. These hold the thermometer tubes, but prevent the thermometer reservoirs from touching the walls of the boreholes.

Dependable thermal contact between the thermometers and the block is secured by filling the borehole channels with a liquid of low freezing point and substantially constant viscosity in the temperature range between +20 and −20°C (alcohol, kerosene, etc.).

To decrease the amount of heat passing from the surrounding medium to the volume being cooled, a layer of heat-insulation material – microporous rubber – is interposed between the aluminum block and the wall of the case surrounding it.

* See English translation.

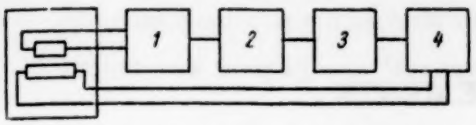

Fig. 2. 1) Signal-emitting bridge; 2) voltage amplifier; 3) power amplifier; 4) rectifier.

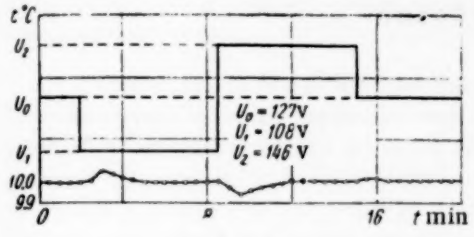

Fig. 3

A protective glass bell is attached to the top cover of the thermocryostat, held there by means of a bayonet lock; the joint is made gastight. This protects the inside working space from accidental air surges, and also prevents moisture from the ambient atmosphere from entering, which is very important when working at temperatures below 0°C.

The vessel for the ice in which the copper radiator is submerged is made of metal and has double walls with the space between the walls filled with microporous rubber. The internal volume of this container is 0.002 m^3; one filling with ice is figured to last for 6 hours of constant working conditions for the thermocryostat.

The thermo-battery consists of 18 thermocouples and has sufficient cooling power to attain temperatures down to −20°C for calibration of four thermometers simultaneously.

An investigation of the distribution of temperatures throughout the working space in the aluminum block has shown that the temperature gradient does not exceed 0.005 deg/cm anywhere, either in the radial or in the axial direction.

For automatic control of temperature, a continuously operating regulating device is employed, which is designed according to the block diagram shown in Fig. 2.

A semiconductor resistor (an MMT thermistor) temperature transducer is used . Its high temperature coefficient of resistance ($\alpha = 0.027$ deg^{-1}), small size, and small thermal capacity permit us to employ it for measurement of temperature of the semiconductor cryostat, in spite of the latter's low thermal capacity. The high absolute resistance of this transducer unit ($R_{20°C}$ = 3300 ohms) makes it possible to disregard the resistances of the lead wires in the bridge circuit of the transducer.

The high-temperature-coefficient resistor is connected as one arm of a balanced Wheatstone bridge circuit. The other arm of the bridge, in balance with the transducer arm, consists of a variable resistance with stepwise adjustment to 24 positions; this makes it possible to set the temperature of the cryostat in steps of 5°C in the range between +20 and 0°C, and in steps of 1°C in the range from 0 to −20°C.

A change of temperature produces a change of the transducer's resistance and unbalances the bridge; the unbalance voltage, whose amplitude and phase are functions of the temperature change, is amplified 2000 times by an ac amplifier.

The amplified unbalance voltage is used to control a power amplifier. After passing the power amplifier, the unbalanced signal goes to a high-power rectifier, which employs two germanium diodes of type VG-10/15.

The rectifier current, after passing through a choke for smoothing out the ripple, goes directly into the cooling battery of the cryostat.

The precision with which a given temperature can be set and held is ± 0.02°C; the time needed for the cryostat to come to a given temperature is 25-30 min.

The effectiveness of the regulation arrangement may be judged by the curve of Fig. 3, which shows the effect on the cryostat's temperature of line voltage fluctuations of ± 15%

It is proposed to replace the aluminum block in the cryostat by a cylindrical beaker of about 100 cc capacity, filled with a thermostatic liquid, which will make it possible to widen the utility range of the device.

It is further planned to employ a more powerful thermo-battery, which will make it possible to widen the temperature range obtainable in the thermocryostat and also to increase the thermal load, that is, the number of thermometers that can be calibrated simultaneously.

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ELECTRICAL MEASUREMENTS

A DIGITAL ELECTRONIC INSTRUMENT FOR PRODUCTION TESTING OF CONDENSERS

V. G. Zhelnov

It is frequently necessary to carry out substandard rejection tests of a large number of condensers of several different nominal capacitance values with great accuracy, say, of the order of 0.2% or higher. The existing commercial models of instruments for measurement of capacity either do not provide such accuracy or require great expenditure of time for carrying out the measurement, a condition which is incompatible with the requirements of mass inspection.

The circuit and setup described below were developed by the author for rejection, on a percentage accuracy basis, of condensers of the following five nominal capacitance values commonly employed in various circuits: 0.013, 0.05, 0.1, 0.2, and 0.4 μf. When necessary, these nominal values can easily be replaced by others. The range of the instrument is ± 5%. Accuracy of the deviation measurements is ± 0.1%. Because of the use of a method in which specific absolute values are obtained for each tested specimen individually, the instrument makes it possible to carry out rejection tests with high accuracy, as well as with low accuracy margins, on the same scale, and without any switching from one range to another.

When the circuit for the instrument was developed, it was decided to chose the beat method, because it is one of the most sensitive. This method is widely used in devices for measurement of nonelectrical quantities using capacitance transducers, and also in some instruments for measurement of capacitances, such as, e.g., the IIEV-1.

There are two oscillators in this instrument: one has an invariable frequency f_0; the frequency of the other can deviate from f_0 by a quantity Δf, which is determined by the magnitude of the deviation of the capacitance under test C_X from its nominal value C_s. Since the maximum value of capacities to be tested is large (0.4 μf), for f_0 a low frequency of 2 kc was chosen, and oscillators operating on the Wien bridge circuit were used. As is well known, the frequency of such an oscillator is determined by the formula

$$f_0 = \frac{1}{2\pi\sqrt{R_1R_2C_1C_s}},$$

where R_1, R_2, C_1, and C_s are the Wien bridge parameters. When capacitance C_s is replaced by capacitance $C_X = C_s + \Delta C$, the frequency is equal to

$$f_0 + \Delta f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_s(1+\delta C)}} = \frac{f_0}{\sqrt{1+\delta C}},$$

where $\delta C = \frac{\Delta C}{C_s}$.

Expanding the last expression into a series, taking into consideration that $\delta C \ll 1$, and discarding all members of the series except the first one, we arrive at

$$\Delta f \simeq -\frac{1}{2} f_0 \delta C. \qquad (1)$$

The error incurred by this approximation will be evaluated below.

Omitting the minus sign, we have from (1):

$$\delta C = 2\frac{\Delta f}{f_0}.$$

The output voltages from the two oscillators are conducted to a mixing stage, at the output of which beats of frequency Δf are obtained. When the heterodyne frequency f_0 remains constant, δC is determined by Δf in a single-valued manner.

For small values of δC, the beat frequencies obtained are of the order of a fraction of a cycle, and the use of pointer-type frequency meters for their determination encounters serious difficulties. Therefore, the determination of Δf in this instrument is carried out by means of counting pulses for a predetermined time interval T_1. An electrical stop watch of type PV-52 with a total counting capacity of 10^3 pulses is used as a pulse counter. By means of a time relay this counter is connected to the output from the amplifier of the frequency difference Δf for the duration of time T_1. Since for each beat pulse the counter operates twice, during the entire time interval T_1 there will be recorded $n = 2T_1\Delta f$ pulses. Substituting for Δf its value from (1), we obtain

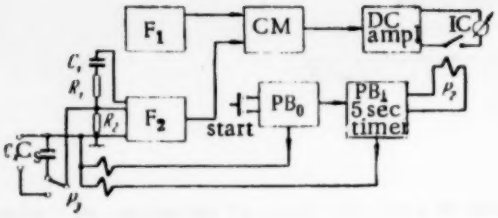
$$n = T_1 f_0 \delta C. \qquad (2)$$

T_1 was set equal to 5 sec. Hence $n = 5 \cdot 2000\delta C = 10{,}000\delta C = 100\delta C\%$.

Consequently, when δC, for instance, is equal to 1%, the PV-52 instrument will record 100 pulses, when $\delta C = 0.1\%$ it will record 10 pulses, and so forth. In the first case the pointer indicating single pulses will have made a complete revolution to show 100, in the second case it will have made 1/10 of a revolution to read 10. Each division on the coarse counting scale indicates a complete revolution of the single-events pointer and corresponds to 1% deviation of the capacitance. Thus, the use of the PV-52 counting device is very convenient, and no change of its scale is needed. In addition, the presence of a return-to-zero arrangement operated by a push button in the PV-52 increases its utility and favorably distinguishes it from other pulse counters such as, e.g., the SB-1M type.

The figure shows a simplified block diagram of the instrument. F_1 is the oscillator that generates the fixed frequency of 2 kc and F_2 is the variable oscillator, whose frequency is determined by capacitance C_x under test. This capacitance is connected to the oscillator only for the duration of the measurement. At all other times, capacitance C_s is connected to the oscillator and maintains its frequency exactly at f_0. The capacitances to be tested are automatically connected to the circuit by means of a switching relay P_3, when the "starter" button is pushed. Owing to the inertia of the stabilizing element of the oscillator, its frequency is not established immediately, but only after the lapse of a certain time interval. To avoid errors due to this process, a time delay relay PB_0 is used which postpones the switching on of the circuit by $T_0 = 2$ sec. It has been established by experiments that this time is sufficient for all transient processes in the oscillator to come to an end. After the delay relay PB_0 has accomplished its purpose, the operational time relay PB_1 is switched on, which causes relay P_2 to operate for 5 sec, thus permitting the counting of pulses coming through during this time. Both oscillator outputs are connected to a mixer stage CM, which is designed along the balanced modulator scheme. The beats obtained at the output from this stage, after the original carrier frequency has been filtered out, go to a dc amplifier. The need for a dc amplifier is caused by the fact, point out before, that the beat frequencies are very low. The amplified signals go to the pulse counter IC by way of the contacts of relay P_2.

The circuits of the two oscillators are completely identical. Tubes 6N2P are used in two-stage amplifier circuits terminated by a cathode follower stage (6N15P [American equivalent 6J6]) employing both positive and negative feedback; the cathode follower serves the purpose of matching the high-impedance amplifier output to the low-impedance feedback circuits. The use of the cathode follower also makes it possible to make the over-all amplification factor quite large – of the order of 5000 – which is extremely important from the point of view of increasing the frequency stability of the oscillators. In addition, the plate voltage supply of the oscillators is stabilized by an electronic voltage control device, and the filament heater supply by a barretter (hot-wire ballast tube), which also contributes to frequency stability. As a result of all these measures, the frequency changes of the generators, after a one-hour warmup period, become very small – amounting only to fractions of a cycle



per hour. For stabilization of the oscillator amplitudes, thermistors of type TP6/2 are included in the negative feedback loops. When the nominal value of the test specimen is changed, simultaneously with the condensers of the F_2 oscillator, all other components of the Wien bridge are switched over to the values necessary to keep the oscillator frequency at 2000 cps. To eliminate the frequency capture effect, the oscillators are carefully shielded from each other; it should be noted that in the breadboard model of the instrument this capture effect made itself felt strongly even when coupling between the tube cathodes was as low as the order of 1-2 $\mu\mu f$.

The balanced modulator operates on 6A2P tubes [American equivalent 6BE6]. To the first grids of these tubes are applied signals coming from the outputs of the cathode followers which are in phase, and to the third grids, signals that are in phase opposition, coming from a phase inverter. The magnitude of each of the signals can be smoothly varied by means of potentiometers, and thus the most advantageous balanced conditions for the operation of the modulator can be selected. From the modulator output the beat frequency oscillations go through an RC filter to the input of a symmetrical amplifier using a 6N2P tube. The next stage is a class C power amplifier employing 6P14P tubes. Thanks to this design, there is complete absence of drift in the amplifier's output, which if present would lead to changes in the magnetization of the pulse counter's coil and upset the normal operation of the counter.

The delay relay PB_0 employs a 6N1P tube; the timer relay PB_1 employs a 6N2P tube. The circuits around both of these tubes are of the same type; both tubes and the other components associated with them form a Schmitt trigger circuit. The triode on the left side of the Schmitt circuit diagram is normally in the blocked condition, while the triode on the right is open. When a condenser charged from a plate potential to 250 v is connected to the grid of the left triode, a snap-action upsetting of the circuit occurs which puts the relay in the plate circuit into operation. This condition is maintained while the condenser is discharged until the potential on it has fallen to a certain limit value, at which the circuit – again with snap action – returns to its initial condition. As was shown by experiments, this circuit, in spite of its simplicity, is distinguished by sufficiently high accuracy – of the order of 1%. To increase the accuracy, the filament and plate voltage supplies of the second relay (the 5-sec timer) are stabilized.

Operation of the instrument is started by pushing a button marked "start". This, first of all, sets into operation the mechanism carrying out the return to zero of the PV-52's electrical stop watch pointer from its last position. Since the delay relay PB_0 (left side of the Schmitt circuit) is normally in the blocked condition, no further switching action occurs for a little while. But when the plate of the right-hand triode in the Schmitt circuit swings positive, the armature of two-position relay P_3 is thrown over into the position in which capacitance C_X is connected to oscillator F_2. The condenser in the second relay circuit is connected to the plate voltage source and is fully charged. After 2 seconds have elapsed, relay PB_0 goes out of operation and starts time span relay PB_1, which connects the pulse counter to the output of the power amplifier and thus starts the measurement. At the end of the measurement, the potential on the plate has swung to a negative value, which returns the armature of relay P_3 to its initial position, connecting a standard-value capacitor to oscillator F_2 in place of the one tested.

A manual switch is provided in the instrument, by means of which the operation of the oscillators and of the time relay PB_1 can be checked. In one position of this switch, the pulse counter is connected to the amplifier output, and by changing the setting of an adjustable resistance in the circuit, zero beats are obtained. With the switch in the other position, the pulse counter is connected to the 50 cps line, and the 5-sec setting of the timer relay is checked. For determination of the sign of the error in the F_1 oscillator, a special rheostat, variable by rotation of a shaft, is incorporated: the sign is determined by the direction of the rotation of the shaft which decreases the beat frequency.

There are several sources of inaccuracy in this instrument.

Inaccuracy caused by lack of constancy of the standard condensers' capacities C_s. When the actual value of standard capacity C_s is lowered by ΔC_s, then there is an error Δ_1, which is

$$\Delta_1 = -\frac{\Delta C_s}{C_s}.$$

This source of inaccuracy is most serious, because it requires the use of very stable and constant condensers. However, when the inspection tests are carried out only for a limited span of time (several hours), and the requirement of a warmup period of one hour prior to actual testing has been fulfilled, this inaccuracy has a constant value, and, therefore, can be taken care of by introduction of a corresponding correction. When only relative inspection tests of condensers are required, as is the case most of the time, this correction is not required.

Inaccuracy caused by deviations of the timer relay PB_1. On the basis of equation (2) above, this inaccuracy is

$$\Delta_2 = \delta C \delta T_1$$

where δT_1 is the variation in the total counting time T_1. As was pointed out above, the instability of the timer relay PB_1 is not over 1%. Thus, e.g., when a deviation of capacitance $\delta C = 10^{-2}$ is measured, the inaccuracy Δ_2 will be 10^{-4}, that is, 0.01% of the nominal capacity of the test specimen.

Observational errors of every individual test on the instrument amount to ± 1 division of the single-pulse scale, that is,

$$\Delta_3 = 10^{-4}, \text{ or } 0.01\%.$$

Error due to inaccurate adjustment of the oscillator frequency to 2000 cps. This error, on the basis of (2), is equal to

$$\Delta_4 = \delta C \delta f_0,$$

where $\delta f_0 = \Delta f_0 / f_0$. The frequency of the oscillators is adjusted with an accuracy of the order of one-tenth of a cycle. Hence, Δ_4 is smaller than 0.01%.

Inaccuracy due to inequality of the frequencies of the two oscillators at the start of a test. This is

$$\Delta_5 = 2 \frac{\Delta f_p}{f_0},$$

where Δf_p is the difference in the frequencies of the oscillators prior to the test. Because of the fact that the circuits of the two oscillators are identical, and thanks to the stabilization measures for maintaining these frequencies constant incorporated in the apparatus, the deviation from the zero beat condition does not exceed 0.2 of a cycle for every consecutive hour of operation, which corresponds to a relative error of 0.02%. When working with this instrument, checks for, and adjustment to, zero beat are carried out periodically.

The systematic error incurred when, in deriving (1), the second and subsequent members of the series were discarded, is

$$\Delta_6 = -\frac{3}{4} \delta C^2.$$

When $\delta C = 10^{-2}$, $\Delta_6 = -0.75 \cdot 10^{-4}$, or 0.0075%.

CONCLUSION

The analysis of the inaccuracies involved, given above, and experimentation on a breadboard model of the instrument justify the conclusion that, when high-stability condensers are used in the arms of the Wien bridge, rejection of condensers deviating from their nominal value can be carried out by means of this instrument with an accuracy of the order of 0.1%, and rejection relative to a standard of comparison with an accuracy of the order of 0.05% is possible. It should be noted that lack of constancy of the other components of the two Wien oscillator bridges is of no importance, because their change will not produce the Δ_1 inaccuracy, but only inaccuracies Δ_4 and Δ_5, which are very small. When ordinary condensers are used as standard capacities C_s, the instrument will guarantee a relative accuracy of at least 0.1% in routine acceptance tests, and even better accuracy in spot tests.

Engineer Yu. L. Sokolov took part in the experimental work on this device and in the working out and adjustment of the breadboard model.

ON THE OPERATION OF THE VIBRATING-REED INVERTER IN A DC AMPLIFIER

V. Z. Naiderov

Direct-current amplifiers using vibration devices (choppers) for inversion to alternating current have found wide application in various measuring instruments and, among others, in industrial automatic potentiometer recorders. There are in the literature descriptions of different versions of amplifier input stages using vibration-type inverters. However, a number of problems connected with these have not been sufficiently cleared up, or have been treated in different ways which have led the authors to results disagreeing with each other. Thus, some deductions and statements of [1] and [2] need substantial amendment to make them more accurate.

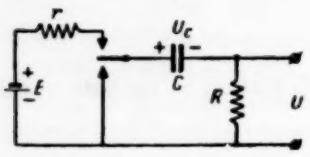


Fig. 1

The problems that need additional investigation include the determination of the time it takes for a voltage to come through to the output of a circuit using such an inverter, and also the determination of the mean value for the input impedance to such a circuit.

We shall examine in this paper one of the circuits most frequently used for this purpose (Fig. 1). E, here, is a constant dc input potential; for the sake of simplicity, we shall assume that E = 1; r is the internal resistance of the source of potential E.

Time for establishment of steady-state output voltage. In order to obtain at the output of the inversion circuit voltages that are close in shape to square pulses, and in order to assure a sufficiently high input impedance, it is necessary to chose the time constants of the charge and discharge loops of the condenser C so that they are considerably larger than the commutation period of the inverter's vibrator. The duration of the inversion process of the dc to ac in the input loop of the amplifier plays an important role when the amplifier is used in a fast-acting measuring setup, such as, for instance, an automatic compensation device, or when the object is to measure rapidly changing potentials.

In determining the duration of the inversion process in the input circuit, we shall make the following assumptions:

Let the duty ratio of the voltage pulses at the output from the inverter be $\gamma = 0.5$, and let $r \ll R$, that is, let the sources of the input voltage have a very low resistance in comparison with the effective resistance R of the inverter circuit. Under this condition, the time constants of the charge and discharge stages can be considered to be the same and equal to $\tau = RC$.

The expressions for the condenser voltages during its charging period (u_{c_c}) and during its discharging period (u_{c_d}) are then as follows:

$$u_{c_c} = 1 - (1 - U_{c_0})\, e^{-\frac{t}{\tau}};$$

$$u_{c_d} = U_{c_0} e^{-\frac{t}{\tau}},$$

where U_{c_0} is the initial voltage value on the condenser.

Placing the zero points of the time axis at the starting moments of the charge and discharge of each commutation period, we have at the ends of the halves of the mth commutation period

$$U_{c\,c(m)} = 1 - [1 - U_{c_{d(m-1)}}]\, e^{-\frac{T}{2\tau}},$$

$$U_{c_{d(m)}} = U_{c_{c(m)}} e^{-\frac{T}{2\tau}},$$

where T is the period of commutation.

m	U_c at the end of 1st half period	ΔU_{cc} Increm. dur. charge	U_c at the end of 2nd half period	ΔU_{cd} decrem. dur. discharge
1	$1-\mu$	$1-\mu$	$\mu-\mu^2$	$1-2\mu+\mu^2$
2	$1-\mu+\mu^2-\mu^3$	$1-2\mu+2\mu^2-\mu^3$	$\mu-\mu^2+\mu^3-\mu^4$	$1-2\mu+2\mu^2-2\mu^3+\mu^4$
3	$1-\mu+\mu^2-\mu^3+\mu^4-\mu^5$	$1-2\mu+2\mu^2-2\mu^3+2\mu^4-\mu^5$	$\mu-\mu^2+\mu^3-\mu^4+\mu^5-\mu^6$	$1-2\mu+2\mu^2-2\mu^3+2\mu^4-2\mu^5+\mu^6$

After denoting $e^{-T/2\tau}$ by $\mu(\mu < 1)$, we obtain the following expressions for the condenser voltages U_c at the end moments of the first six half-periods (see table).

Here

$$\Delta U_{c\,c(m)} = U_{c\,c(m)} - U_{c_{d(m-1)}},$$
$$\Delta U_{c_{d(m)}} = U_{c_{c(m)}} - U_{c_{d\,(m)}}.$$

For the m th period we have

$$U_{c_{c(m)}} = 1-\mu+\mu^2-\ldots\ldots-\mu^{2m-1}; \quad (1)$$

$$U_{c_{d(m)}} = \mu-\mu^2+\mu^3-\ldots\ldots+\mu^{2m-1}-\mu^{2m}. \quad (2)$$

$$\Delta U_{c_{c(m)}} = 1-2\left(\mu-\mu^2+\mu^3-\ldots-\mu^{2m-2}\right)-\mu^{2m-1}; \quad (3)$$

$$\Delta U_{c_{d(m)}} = 1-2\left(\mu-\mu^2+\mu^3-\ldots-\mu^{2m-2}\right)-\mu^{2m-1}+\mu^{2m}. \quad (4)$$

Keeping in mind that (1), (2), (3), and (4) are convergent series, let us determine the value of m at which the mean voltage on the condenser can be considered established with a given degree of accuracy.

This can be done in two ways. Taking the first way, we can prescribe that the difference $\Delta U_{c_{c(m)}} - \Delta U_{c_{d(m)}}$ be equal to a certain small quantity Δ_1, that is, we determine m from the condition

$$\Delta U_{c\,c(m)} - \Delta U_{c_{d(m)}} = \Delta_1.$$

Using (3) and (4) above, we obtain the transcendental equation

$$\mu^{2m-1}(1-\mu) = \Delta_1.$$

However, this method is inconvenient because of the absence of a universally accepted criterion for the value that should be selected for Δ_1.

It is more convenient to proceed by finding an expression for the mean voltage value on the condenser as a function of the number of commutations m.

We define the mean voltage on the condenser as the half-sum of the voltages at the ends of the first and second half-periods, that is,

$$U_{c_{av}} = \frac{U_{c_{c(m)}} + U_{c_{d(m)}}}{2}.$$

We then have by means of (1) and (2)

$$U_{c_{av}} = 0.5\left(1-\mu^{2m}\right)$$

and after substitution of the value of μ, we finally have

$$U_{c_{av}} = 0.5\left(1-e^{-\frac{mT}{\tau}}\right).$$

It is evident from this that when $\gamma = 0.5$ and $r \ll R$, the mean voltage on the condenser of the inversion stage is an exponential function, approaching a steady-state value equal to one-half of the input voltage.

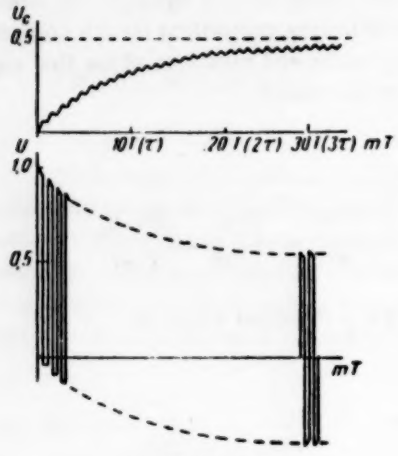


Fig. 2

The time for reaching this steady-state condition, as is well known, is assumed to be equal to 4τ, with a possible error of $\sim 2\%$.

Let us find a general expression for m. We consider that the process has practically reached steady-state conditions, when the condenser voltage U_c differs from the steady-state voltage U_{st} by:

$$\Delta = \frac{U_{c\,st} - U_c}{U_{c\,st}} \text{ rel. units.}$$

From this we obtain: $e^{-mT/\tau} = \Delta$, or

$$m = -\frac{\tau}{T} \ln \Delta,$$

which for a deviation of 2% ($\Delta = 0{,}02$) amounts to $m \simeq 4\tau/T$.

In Fig. 2 two curves are shown: one for the voltage on the condenser U_c, and the other for the output voltage U from the circuit loop, when $E = 1$, $\tau = 10\,T$, and $\gamma = 0.5$.

Thus, the expression given in [1] for the time needed for establishment of a steady state in the output from a vibratory inverter, which is $m \sim \tau/T$, may result in a considerable error in cases when the inertia of a system of dc amplification plays an important part. The inaccuracy of this expression is due to the fact that in its deduction certain factors were – improperly – neglected.

Input impedance. The main input impedance of a circuit with a vibrational inverter is determined, as usual, by the ratio of the input voltage to the average value over one commutation period of the input current.

When $\gamma = 0.5$ and $r \ll R$, the steady-state output voltage pulse amplitudes are

$$U = E - U_{c\,av} = \frac{E}{2},$$

where U is the voltage across resistance R (Fig. 1).

Current is drawn from the source only when the vibrator armature is making contact in the upper position of Fig. 1; therefore, the input current, when $\gamma = 0.5$, is present only during one-half of the commutation period, and represents unidirectional pulses of $T/2$ duration, whose amplitudes when steady-state conditions are reached, are equal to

$$i_m = \frac{U}{R} = \frac{E}{2R}.$$

The average value of this current over its duration $T/2$ is

$$i_{av} = \frac{i_m}{2} = \frac{E}{4R}.$$

From this, the average value of the input impedance to this circuit loop is equal to

$$R_{in.av} = \frac{E}{i_{av}} = 4R.$$

Thus, the average value of the input impedance to the circuit is four times the value of the so-called effective resistance of the input stage [1].

In connection with existing indications [1, 2] that the average value of the input impedance can be considerably lower than the effective resistance, because during a certain part of the period (up to 7%) the inverter

contacts remain closed longer than they should due to oscillations of the armature, an experimental investigation of the input impedance of a vibratory inverter, type VP-55,was carried out. The measured value for the average input impedance was equal to the computed value within an accuracy of 2%. The relative time during which the vibrating armature was making contact in each of the two positions was 43% of the period. Therefore, the average value of the input impedance was not 4R, as it should be in the ideal case when $\gamma = 0.5$, but about 4.7R.

CONCLUSION

This investigation provides more accurate deductions and results than those obtained before [1, 2]; these results can be utilized in the design of automatic recording instruments for varying dc voltages, and also in the design of instruments which must meet the requirements for high input impedance.

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CHECK TESTING OF INDUCTION-TYPE STANDARD METERS BY A THERMOELECTRIC METHOD

I. N. Osher and I. I. Bobkovskaya

In view of the insufficient accuracy of the usual method of checking standard electric meters by means of a wattmeter and a stop watch, the authors utilized a potentiometer set of type UV-1, made by the "Etalon" factory, for measurement of electrical power.

Current load, %	cos φ	Deviation in UV-1 test, %	Deviation from arithmetic mean, %
100	1	±0	+0.1
50	1	+0.3	+0.3
100	0.5	+0.2	+0.3
100	1	+0.2	+0.1
50	1	+0.2	+0.1
100	1	+0.1	±0
50	1	−0.1	±0
100	0.5	−0.2	±0
100	1	−0.1	−0.1
50	1	−0.2	−0.3
100	0.5	−0.5	−0.3

The UV-1 set is made for testing of wattmeters by a thermoelectric method; inaccuracy of power measurements by this instrument does not exceed ± 0.05% when $\cos\varphi = 1$, and ± 0.1% when $\cos\varphi = 0.5$, at frequencies from 50 to 1000 cps.

Electrical energy for testing of the meters was obtained from a three-component power supply set, consisting of two synchronous generators and a motor driven by a storage battery.

During testing of the meters by the UV-1 set, the power was kept constant by means of a mirror-type galvanometer in the comparator circuit of the set. Thanks to the high sensitivity of the galvanometer, accurate maintenance of load constancy was possible without any strain on the eyes of the observer in view of the fact that deviations of the light spots on the scale of 4-5 mm are admissible without affecting accuracy of test results.

Time was measured by a stop watch with a possible error of not more than 0.1 sec in a 100-sec interval. The time intervals used in these tests were never less than 180 sec, and thus the possible error of any time measurement did not exceed 0.06%.

The probable over-all error in a check test of a meter at $\cos\varphi = 1$ by this method thus is

$$\Delta = \pm 2/3\sqrt{0.05^2+0.06^2} = \pm 0.06\%.$$

Similarly, at $\cos\varphi = 0.5$ we find

$$\Delta = \pm 2/3\sqrt{0.1^2+0.06^2} = \pm 0.08\%.$$

Frequency is kept constant by means of a frequency meter of class 0.2.

Four standard meters were tested by the described method. With small loads the meters' operation is less stable than with large loads; therefore, in the table below giving test results for four meters, data are included for 50% as well as for 100% standard load conditions. Also data for $\cos\varphi = 0.5$ phase conditions, in addition to those for $\cos\varphi = 1$, are given.

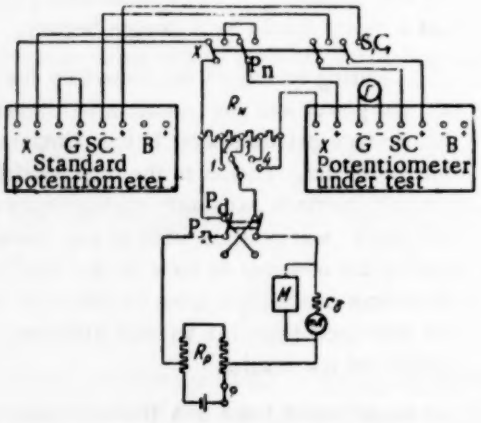
The meters were taken from a lot of 18 meters of the same kind, obtained in 1958 from the CDC Company. A comparison of readings obtained with each of the 18 meters for a number of different loads was carried out; for each load the arithmetic mean of readings on 18 meters was determined, and the deviation of each of the obtained readings from the mean was noted. The discrepancies between the test results obtained by means of the UV-1 set and the corresponding deviations from the arithmetic mean are all within the limits of 0.1%, except in two cases, when the discrepancy is as much as 0.2%. This can be considered indirect proof of the correctness of the tests by means of the UV-1 set.

This investigation has shown that the use of a UV-1 set for check testing of standard electric meters is a real possibility.

IMPROVEMENT OF THE DIFFERENTIATION CIRCUIT FOR TESTING OF POTENTIOMETERS WITHOUT A STANDARD CELL

S. M. Kal'f-Kalif

In this paper a modified circuit network for measuring potential differences is presented which makes it possible, when testing potentiometers, to obtain readings in a simple way without the use of a standard cell.



Testing of potentiometers without the use of standard cells has the following advantages [2, 3]:

1) There is no more need for having one or more standard cells in the apparatus.

2) The number of adjustments of the operating current is reduced from two to one.

3) Increase of sensitivity is possible by simply increasing the operating current, within required and permissible limits.

However, the customary circuit network for potential difference measurement as described in [1, 2] is inconvenient, because when the operating current in the standard potentiometer and in the potentiometer under test is increased by a factor of $K (1 < K \leq 4)$, the readings of the milliammeter must be divided by K, and the latter can have different values (mostly not in whole numbers) depending in every

specific case upon the required increase in sensitivity and upon some of the special characteristics of the potentiometers. The modification of a difference-measuring circuit described in [3], which is designed specifically for testing of potentiometers without the use of a standard cell, also does not get rid of the necessity for carrying out a division operation when computing the results of measurement.

The difference measuring circuit network (see figure) also provides a simplified way of calculating errors incurred during testing of potentiometers without a standard cell. In the present circuit there is a resistance r_δ connected in series with the milliammeter, and a resistance box M connected in parallel to both the milliammeter and resistance r_δ; this makes it possible to change the range of currents to be measured at will. Resistance r_δ is used in series with the milliammeter because the resistance of the latter is low, and adding the resistor in series makes it possible to use the higher resistances available in standard resistance boxes of types KMS-6, R-32 and others for shunting. The degree of accuracy of the resistance box is of no importance in the present circuit.

There are four ranges provided: up to 15, 75, 150, and 1500 μv. The range required for a specific measurement is turned on by switch P_d. The switching arrangement does not differ from the one described in [3].

After the operating currents for the various ranges have been established, a calibration of the measurement setup must be made. This is carried out in the following manner. Switch P_d is turned to position 4 (see figure); the standard potentiometer is adjusted to the nominal standard output (1000 μv); on the potentiometer under test all decades are set to zero; the switches on the potentiometers are turned to the position marked "measurement", switch P_n of the test apparatus is turned to position X, and then by means of rheostats R_p the milliammeter mA is loaded more and more until the pointer is on 100. Tapping the momentary contact switches on the galvanometer G and adjusting rheostat R_p, complete compensation (zero current) between the two potentiometers is achieved, while the pointer of the test meter mA is kept on the 100 mark by changing the resistance in the shunting box M.

After that, inspection tests of a number of instruments can be started. The differences between instruments under test and the potentiometer used as a standard are no longer connected with absolute voltage values, but are usually determined by the formula

$$U_0 - U_x = \pm I_d R_d,$$

where I_d is the current indicated by the milliammeter, and R_d the equivalent resistance of the circuit network of the difference-measuring apparatus in which current is flowing.

In the described circuit, a milliammeter of class 0.5 and type LM-1 is conveniently used with a full-scale deflection of 1.5 ma.

When this milliammeter is used, the equivalent circuit resistance with switch P_d in position 1 is 0.01 ohm, in position 2, 0.05 ohm, and so forth, corresponding to the ranges mentioned above. This resistance must be adjusted to the required values with an accuracy of 0.1%.

The value of r_δ with the above circuit parameters is 1000 ohms.

The described arrangement, which simplifies the testing of potentiometers without standard cells, has been employed in the electrical measurements laboratory of XGIMIP* for testing of high-ohmage potentiometers and potentiometers of types PN-4 and PN-4-1.

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* Kharkov State Institute for Measures and Measuring Instruments.

METHOD FOR ADJUSTMENT AND SENSITIVITY CONTROL OF A POTENTIOMETER-TYPE VOLTMETER

V. S. Golub

The method offered herein for adjustment and sensitivity control of potentiometer-type voltmeters, in which the circuit of the indicating meter has low resistance, is distinguished from other known methods by higher accuracy.

Figure 1 shows a simplified circuit diagram of such a voltmeter. A pointer-type indicating instrument, such as, for instance, a microammeter having its zero in the middle of the scale, is used to indicate the magnitude of the deviation ΔE_0 of the measured potential $E_X = E_0 \pm \Delta E_0$ from the value of E_0. When there is no current going through the indicating meter, we have

$$E_0 = E\frac{R_2}{R_1+R_2}.$$

To obtain a desired angular deflection of the meter pointer for a certain value of $\pm \Delta E_0$ there is a simple, however not very accurate, method; it consists in applying a potential $E_0 + \Delta E_0$ or $E_0 - \Delta E_0$, measured by any potential measuring device, to the input terminals of the voltmeter and selecting a value for resistance r* in series with the meter which will produce the desired deflection. The smaller the percentage ΔE_0 is of E_0, the lower the accuracy of this method.

In distinction to the above-mentioned method, the method described in this paper consists in applying to the voltmeter terminals only the potential $+\Delta E_0$ or $-\Delta E_0$ while the voltmeter's power supply is disconnected and the connecting leads from the voltmeter to the power supply are short-circuited (Fig. 2). Resistance r* is then so selected or adjusted that the indication of the microammeter corresponds to the value of ΔE_0 applied to the voltmeter's input terminals.

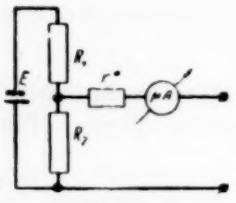

Fig. 1

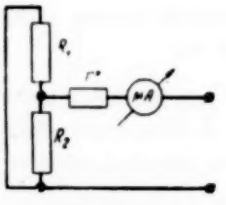

Fig. 2

The theoretical basis of our method is the theorem of the equivalent generator [1], well known in electrical engineering.

Mathematically, r* is given by the following expression:

$$r^* = \frac{\Delta E_0}{I} - \frac{R_1R_2}{R_1+R_2} - r_m$$

where I is the current going through the indicating meter and r_m its resistance.

After the additional resistance r* has been properly adjusted by our method, the instrument when used again with the circuit connections of Fig. 1 will show the values of $\pm\Delta E_0$, when $E_X = E_0 \pm \Delta E_0$ is measured.

In case high accuracy is not required, it is sufficient to determine the value of r* by the above formula, without an individual experimental adjustment.

This method has been used by the author for sensitivity adjustment and control of a potentiometer-type voltmeter in setups wherein the value of E_0 is automatically changed in proportion to the supply voltage E, while

the values of $\pm\Delta E_0$ do not depend on E_0 or E, but on other factors for the control of which the potentiometer-type voltmeter is being used.

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A DEVICE FOR REMAGNETIZING MAGNETS IN INSTRUMENTS UNDER REPAIR

A. I. Rusakov

In repairing moving coil instruments, weakened permanent magnets are sometimes encountered.

This weakening is due to the dismantling of the moving systems of the instruments, and the closing of the magnetic circuit during repairs does not prevent its taking place. After assembly, such instruments have a negative error. Normally this error is corrected in repair shops by changing the values of the multiplying resistors or by replacing hair springs. These methods are bad since, among other things, they make instruments nonstandard. A correct solution, in this instance, is the restoration of the original properties of the magnet. Designs of equipment for magnetizing and ageing of magnets is described in technical literature, but they are not suitable for workshop conditions.

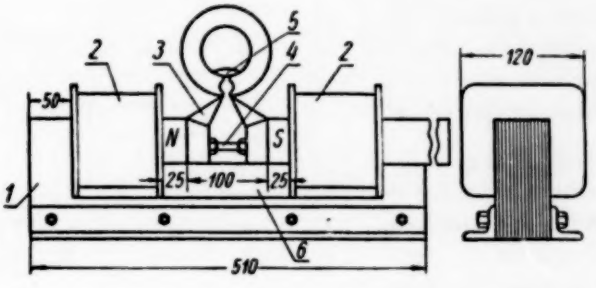

Fig. 1

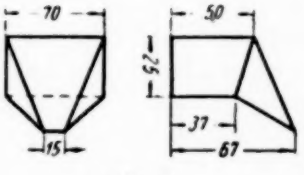

Fig. 2

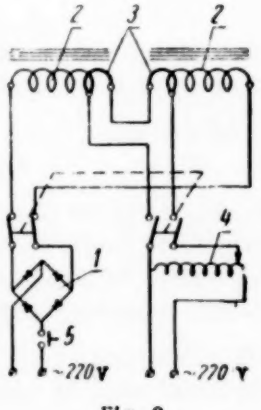

Fig. 3

We have designed a simple apparatus which satisfies the requirements of workshops, taking into consideration the variety of the instruments which they have to repair (Fig. 1). It consists of a yoke 1 of cross section $S = 35\ cm^2$ made of transformer steel, with coils 2 which are fed by dc (the coil circuit is shown in Fig. 3). Pole pieces 3, made of St. 3 steel or Armco iron, serve to provide a uniform magnetic field and are fastened together with a brass pin 4. The dimensions of the pole pieces are given in Fig. 2. A magnetic shunt made of the same material as the pole pieces is also used in the equipment. Aluminum bar 6 serves to fix the position of coils 2. It is also used as a support for magnets (of instruments M80, M82, and M21) which are placed for remagnetization between the N and S poles, or for supporting pole pieces 3, which are used in remagnetizing circular magnets of type M24 instruments.

Let us note that in restoring magnets of instruments M80 and M82, a core, consisting of Armco iron pressed into a brass tube, the thickness of whose walls is equal to the air gap between the poles and the moving coil, is inserted between their poles.

The coils are fed from rectifier 1 (Fig. 3), since a direct current provides a predetermined polarity to the magnet. Rectifier 1 is of the bridge type, consisting of selenium washers of 100 mm diameter. Each arm of the bridge contains three parallel piles of 12 washers each. Coils 2 are wound with 1700 turns each of 1 mm PBD wire. An additional winding 3 of 200 turns of 1.5 mm diameter wire is connected in series with each main winding. These additional windings have separate leads to which transformer LATR-1 is connected (4), which provides an ac supply smoothly variable from zero to the full value. This is required for an artificial ageing of magnets. The rectifier is connected to a 220 v line. It uses a current of some 7 amp. The magnetization process lasts 1-2 sec and is accomplished by pressing button 5.

MEASUREMENTS AT HIGH AND SUPERHIGH FREQUENCIES

A TRANSISTORIZED UNIVERSAL ELECTRONIC COMPUTER

G. P. Vikhrov

The pulse-counting method is very convenient for measuring any values. It has the following advantages as compared with other methods: 1) speed of measurement combined with high precision; 2) figure display of the measured parameter; 3) ease of operation; 4) possibility of making measurements automatic.

Electronic pulse counters consisting of tubes are usually large, heavy, and use considerable power.

Below we describe a transistorized electronic computer with a capacity of 10^{-5} to 1, free from these defects and designed to measure either the frequency or period (10^{-5} to $1.5 \cdot 10^{5}$ cps) and time intervals (10^{-4} to 10^{5} sec) of electrical signals with an error not exceeding $\pm 2 \cdot 10^{-5} \pm 1$ count.

The block schematic of the instrument is shown in Fig. 1.

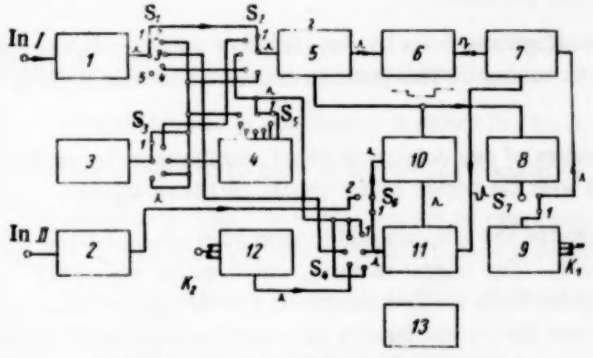

Fig. 1. 1) Shaping device of the input socket In I; 2) shaping device of the input socket In II; 3) crystal oscillator; 4) dividing stages; 5) signal selector; 6) counting stages; 7) restoring generator; 8) interval generator; 9) single-pulse generator; 10) selector trigger; 11) blocking trigger; 12) single-pulse generator; 13) power pack.

The measurement of frequency amounts to the counting of the number of pulses equal to the number of periods of the incoming signal over a sufficiently accurately known period of time set by the crystal oscillator 3.

In order to obtain a direct count, the value of this time interval is set at 10^{n} sec, where n is a whole number between 1 and -5, including zero. These time counts are obtained by dividing by the required factor the crystal oscillator frequency of 100 kc. The division is made by means of counting-circuit 4 consisting of six stages.

The input signals (both sinusoidal and pulsed) are fed to device 1 which forms positive pulses used to operate the subsequent stages. Shaped pulses are then fed to the input of the signal selector 5. The selector is operated by a controlling rectangular negative pulse, whose duration is set by the crystal oscillator 3. The pulses which pass from the shaping device through the selector during the time it is made operative by the controlling pulse are counted by the computer circuit 6 consisting of five stages.

The remaining parts of the circuit serve to provide the required working conditions for the signal and counting stages.

In the initial position the selector 10, and blocking 11, triggers provide the blocking of the signal selector and are not tripped by the pulses received at their left-hand-side inputs from the dividing stages (time base). The interval generator 8 pulse trips the blocking trigger 11, but does not operate the selector trigger 10. Simultaneously the restoring generator 7 pulse returns the counting stages 6 to their initial positions.

The next pulse of the time base returns the blocking trigger 11 to its initial position and thus trips selector trigger 10 which in turn makes the signal selector 5 operative. The next pulse of the time base returns the selector

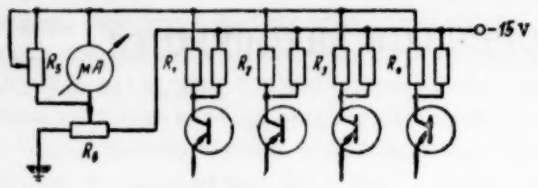

Fig. 2

trigger 10 to normal and blocks the signal selector 5. The circuit remains in a stable condition until the next pulse from the restoring generator 7 is received.

Thus the controlling pulse is formed whose duration is equal to that of one sequence of time base pulses.

The restoring generator can be controlled either by the interval generator 8 or by push-button K_1. The first method provides automatic computer control and the second, manual control.

In automatic control the interval generator 8, which sets the time delay, is started by the trailing edge of the controlling pulse. At the end of the set time the interval generator produces a pulse which sets the beginning of a new cycle of measurements.

It is known that the error of measuring frequency by means of such a computer can be expressed by a sum $\pm \delta_k \pm 1$ count, where δ_k is the relative error of the crystal oscillator frequency. It is obvious that for low frequencies the error increases and can attain intolerably large values unless the counting time is increased, which is very inconvenient. Therefore, in order to raise the accuracy of measurement, it is better to measure the period instead of the frequency of the signal.

The period is measured by counting the number of pulses of the time base during a time interval set by one or 10^n periods of the input signal. The frequency measuring circuit is now, as it were, reversed.

In position 2 of the operation selection switch, input signals are fed to the dividing stages of the time base. The signal selector now receives pulses from the 100 kc crystal oscillator.

In position 3 of the operation selection switch the counting time is set by one period of the input signal only. In this position, time base pulses of various frequencies can be counted. This position is used for measuring long periods.

The measurement of the time interval between two pulses of any polarity is based, similarly to the measurement of one period, on comparing the measured interval with the period of the crystal oscillator signal.

Contrary to the period-measuring condition, in this position the left-hand-side inputs of the selector and blocking triggers are separated (tumbler switch S_6 is operated). The trigger selector, which makes the signal selector operative, is tripped and the counting started by a pulse from the first input In I, and the trigger selector is returned to normal and the counting stopped by a signal from the second input In II. Time base pulses of various frequencies are counted in this position.

The error in measuring the time intervals is expressed as previously by $\pm \delta_k \pm 1$ count. Contrary to the measurement of periods, in this instance the counting time can only be set for one interval, hence the error of measurement of a time interval is always inversely proportional to its duration.

Continuous counting is carried out by the computer for any period set by hand. This condition of operation is set by the operation selection switch in position 4 and tumbler switch S_6 in position 1. In this position push-button K_1 serves to restore the readings of the counting stages and to trip the blocking trigger, and push-button K_2 serves to start and stop the counter.

The checking position is incorporated in order to be able to control the accuracy of the computer. In this position the pulses of the 100 kc crystal oscillator are counted during a time set by the time base, i.e., in a manner similar to the frequency measuring position.

Since the counting time and the counting signals are provided by the same source, the computer readings will always amount to a value of 10^n or $10^n - 1$, where n is a whole positive number determined by the counting time. Such a method of checking provides a verification of all the basic computer units, thus greatly increasing the reliability of measurement results.

Let us now examine the design peculiarities of some of the computer units.

The counting decade is one of the most important and essential units of the computer.

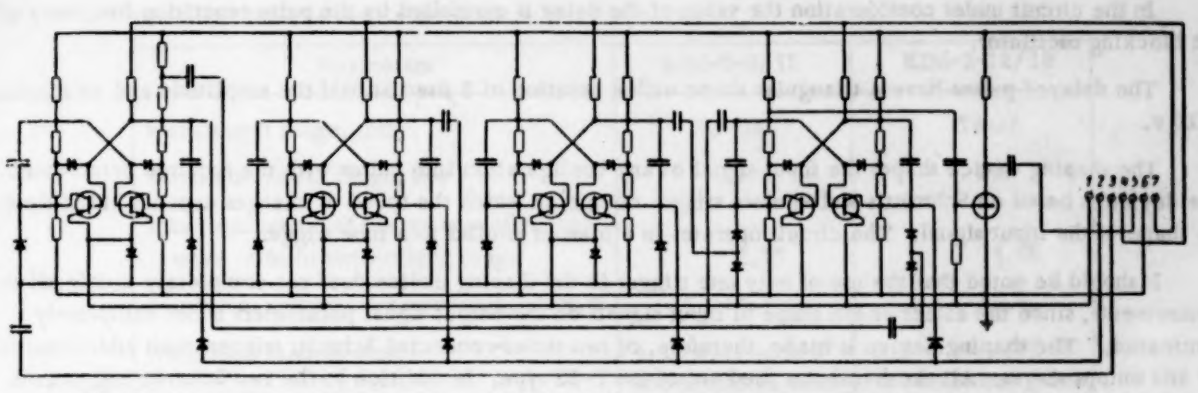

Fig. 3. 1) Common; 2) restoration; 3) input; 4) registering; 5) output; 6) + 10 v; 7) −15 v.

It consists of four double stages with direct coupling and feedback, which provide the conversion of binary counting with a conversion factor of K = 16 to decimal counting with a factor of K = 10. The selected method of interconnections provides a speedy operation and a small delay of the decade output signal, since the tenth pulse triggers the fourth stage directly from the first stage.

The visual indication system of the decade is shown separately in Fig. 2. It is designed on the principle of the summation of currents. The summation circuit consists of a microammeter with a shunt R_5. The values of resistors R_1, R_2, R_3, and R_4 which determine the currents of the stages in the summing circuit are made so much higher than the resistance of the summing circuit that the symmetry of the stages is practically unaffected by these currents.

The relation of the values of these resistors ($R_1 = 8R_4$; $R_2 = 4R_4$; $R_3 = 2R_4$) provides a direct proportionality between current through the microammeter and the number of pulses recorded by the decade.

The schematic of the decade is shown in Fig. 3.

The double stage used in the decade consists of a normal trigger of two P13A transistors.

In order to raise the circuit's speed of operation, the stage has selective feedback established through diodes D_2, D_3, D_8, and D_9, etc. This feedback makes it possible to operate the stages in an unsaturated condition.

Coupling between stages, and feeding of direct and feedback signals and restoring pulses is made through diodes type D-1Zh.

For a reliable operation of subsequent decades or other devices, and in order to eliminate the effect of loading, the decade output signal is shaped by means of a P13A transistor used as grounded emitter amplifier.

The decade is assembled as a detachable unit.

The decade is operated by positive pulses of not less than 3-5 v and a duration of the order of 0.8-2 μsec.

The interval generator is a normal time delay circuit which determines the time lapse between measuring cycles. For convenience of operation the time interval adjusting range is made 1-30 sec.

Time delays of that duration are difficult to obtain by means of normal transistor circuits. This circuit, therefore, employs the principle of accumulating a charge and then comparing the voltage across the storing capacitor with the potential of the discharge circuit.

According to this principle, the interval generator circuit consists of a controlling stage (transistor P-13), which provides external tripping of the blocking oscillator, a capacitance storing circuit (a diode "pump"), and the comparison and discharging circuit.

The stopping of the controlling pulse blocks the controlling stage transistor, and thus starts off the blocking oscillator which consists of a P201 transistor. Positive pulses from the winding of the blocking oscillator transformer are fed to the storing circuit. The potential across the storing capacitor rises up to the firing potential of neon tube MN-3, which discharges the capacitor. Thus, a positive pulse is formed which is delayed with respect to the trailing edge of the controlling pulse.

In the circuit under consideration the value of the delay is controlled by the pulse repetition frequency of the blocking oscillator.

The delayed pulses have a triangular shape with a duration of 3 μsec at half the amplitude and an amplitude of 10 v.

The shaping device shapes the input signal of any configuration into pulses with the required parameters. The device is based on Schmitt's well-known trigger circuit, in which the speed of changes depends but little on the shape of the input signal. The circuit operates in a manner similar to a tube trigger.

It should be noted that the use of only one trigger in the shaping device does not completely satisfy all the requirements, since the effect of the shape of input signals on the output signal parameters is not completely eliminated. The shaping device is made, therefore, of two series-connected Schmitt triggers with additional input and output stages. All the transistors used are of the P-13 type. In addition to the two Schmitt triggers, the device consists of an isolating emitter follower, a differential pulse amplifier, and an output emitter follower. The shaping device is assembled as a detachable unit. The additional input stages are mounted on the main instrument chassis. These stages consist of a diode limiter and an amplifier which make it possible for the shaping device to work with large amplitude signals.

CONCLUSIONS

This computer is a very convenient, automatically operating instrument by means of which it is possible to carry out a number of measuring operations in a short time and with great precision. Its small dimensions (440 × 180 × 195 mm), weight (8 kg), and outstanding economy (power consumption of 0.5 w) make it indispensable in laboratories, shops, and under field conditions.

Engineers A. A. Avizhen', K. I. Sakalauskas, A. A. Chernyakov, L. Ya. Kovaleva, and S. A. Yushka participated in the development of the computer.

MEASUREMENT OF POWER IN THE MILLIMETER MICROWAVE RANGE

A. I. Brodskii

The article deals with microcalorimeters, developed by the Khar'kov State Institute of Measures and Measuring Instruments, which have a cooling thermoelement, and provide power measurements of 2-100 mw with an error not exceeding ± 1.5% at waves of 8-12 mm (waveguide 3.4 × 7.2 mm) and 12-18 mm (waveguide 5.5 × 11 mm).

The principle of operation of a calorimeter with a cooling thermoelement consists in replacing the superhigh frequency power by dc power at an unknown temperature of the calorimetric system. The power dissipated in the calorimetric system is absorbed by the thermoelement owing to the Peltier effect, i.e., owing to the cooling of the "cold" junction of two dissimilar metals when direct current is passed through them.

The construction of the calorimeter is similar to that of the 3-centimeter microcalorimeter described in [1].

In order to raise the sensitivity of the calorimeter and lower the possible systematic error owing to the temperature gradient along the calorimetric system, the latter is closed with a double-walled lid, which consists of thin metal sheets separated by lagging material. The use of such a lid reduces the error due to the temperature gradient to 1/15-1/20 of its former value, reducing the sensitivity by only 20%.

In order to reduce the measuring time, a semiautomatic compensation system is used in the calorimeter.

Technical Data of the Calorimeter

Parameters	KIM-2-8/12	KIM-2-12/18
Wavelength range, mm	7.5-12	12-18
Maximum power range, mw	120	120
Maximum value of the voltage standing-wave ratio in the working range	1.16	1.15
Maximum uncorrected systematic error, %	± 0.7	± 0.7
Maximum random error	± 13 μw(± 0.8% of the measured value)	± 14 μw(± 0.8% of the measured value)
Measuring time, min	2-3	
Overall dimensions, mm	240 x 230 x 170	
Weight, kg	10	

A photocompensation amplifier F-16 is used as a galvanometer in the thermocouple battery circuit. The dc power is evaluated by measuring the heater current with potentiometer PPTV. The cooling, heating, and automatic compensation circuits are fed from two 6 v storage batteries.

LITERATURE CITED

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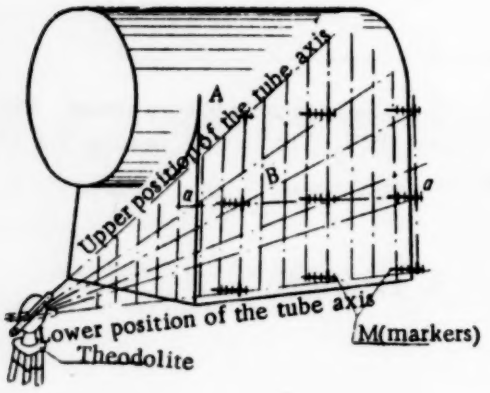
* See English translation.

OPTICAL MEASUREMENTS

AN OPTICAL METHOD OF MEASURING STRAIN IN FLAT WALLS

Yu. A. Magnitskii

Defects inherent in contact methods of measurement do not exist in the optical method of measuring deformations used in the Rostov Institute of Railroad Engineers for determining temperature strains in a flat side-wall of an L series locomotive fire-box.



The essence of the method consists of the following.

A theodolite is placed on a base separated from the surface to be measured in such a manner that its vertical hairline is parallel to the measured surface. Markers with scales attached are placed perpendicularly to the measured surface (see figure, position M). When the theodolite is rotated in the vertical plane its vertical hairline traces the measuring (basic) plane (position B) which crosses each marker scale in some definite place. Let us call the crossing points which are marked with thick lines the reference measuring points. When the wall becomes strained, the markers are displaced together with it. The difference in readings is equal to the displacement of the point to which the marker is fixed. Readings of all the markers are taken before the wall is heated (before its temperature deformation) and after the wall is heated (when it is deformed).

The scale graduations were taken as 0.1 mm (a slanting scale with a 1 mm base). Tests have shown that at a distance of 5 m the scale could be seen with sufficient clarity.

The error of measurement consists of the following components. a) The error due to the unequal expansion of the markers is determined by the difference in the elongation of markers heated up to different temperatures:

$$\Delta l' = \alpha l \Delta t_m, \tag{1}$$

where α is the temperature coefficient of the marker material; l is the length of the marker; Δt_m is the difference in the mean temperature of the hottest and coolest marker.

b) The error due to the slanting of the markers is equal to the displacement of the scale in a direction perpendicular to the base plane. For an angle of slant of the marker equal to φ this error amounts to:

$$\Delta l'' = l(1 - \cos\varphi). \tag{2}$$

The error due to the maximum observable displacement of two markers caused by refraction is equal to

$$\Delta l''' = L\Delta n, \tag{3}$$

where L is the largest distance between the markers (depends on the clarity with which the scale of the furthest marker can be seen); Δn is the difference in the refractive indexes of air near the markers at different temperatures:

$$\Delta n = f(\alpha_B;\ B;\ t_1;\ t_2),$$

Scale graduations δ, mm	l, mm	Δt_m °C	B mm	φ	Referred relative error of the measuring equipment $\frac{2\delta}{l}100$, %
0.1	1000	31	89	1°40′	0.22
	2000	15	185	1°10′	0.11
	3000	10	277	1°00′	0.07
0.5	2000	77	181	2°30′	0.55
	5000	31	450	1°40′	0.22
	10000	15	930	1°10′	0.11
1.0	10000	31	890	1°40′	0.22
	30000	10	2770	1°00′	0.07
	50000	6	4650	0°40′	0.04

where α_B is the bulk temperature coefficient of air; B is the manometric pressure; t_1 and t_2 temperatures of air near the hottest and coldest marker.

If it is assumed that the air temperature near the markers is the same as that of the markers (the worst case), it is possible to consider that t_1 and t_2 are the marker temperatures. Considering that the difference in the refractive indexes depends to a far greater extent on the difference of temperatures $t_1 - t_2$ than on their absolute value, and also that α_B and B are constants, it is possible to write:

$$\Delta n = f'(t_1 - t_2) = f'(\Delta t_B).$$

The relations between the values of $\Delta l'$, $\Delta l''$, and $\Delta l'''$ can differ, but it is desirable that their sum should not exceed a marker scale graduation.

The table shows for certain given conditions the calculated values at Δt_m, l, and φ for which the total error of measurement does not exceed the values δ of a marker scale graduation.

In these calculations it was assumed that $\Delta l' = \Delta l'' = \Delta l''' = \delta/3$; $\alpha = 12 \cdot 10^{-6}$ /degree; $\alpha_B = 3.66 \cdot 10^{-3}$/ /degree; and B = 760 mm Hg.

It will be seen from the last column on the table that the relative measurement error of the equipment for the conditions cited above does not exceed 0.55%.

For other relations between $\Delta l'$, $\Delta l''$, and $\Delta l'''$ the values of Δt_m, l, and φ change a little. This can be seen from (1), (2), and (3).

Thus by means of the system of equations it is possible to select the conditions for which predetermined accuracy of measurement can be attained. It is also possible to determine with sufficient accuracy the measurement error for given conditions of measurement.

When the fire box was tested in the a–a direction (see figure) the optical measurements were duplicated by mechanical ones, carried out by means of bench extensometers mounted on a pipe which was cooled by running water. The difference in the reading of the two devices did not exceed the value of the marker graduations.

For measuring deformations of vertical (or nearly vertical) walls it is, obviously, convenient to use a theodolite, whereas a levelling instrument is more suitable for horizontal walls. The measuring technique, of course, remains the same.

METHODS OF CONSTRUCTING ELECTRONIC DISCRETE-ACTION DIGITAL-DISPLAY INSTRUMENTS AND THEIR RELATIVE EVALUATION

G. L. Grin

Electrical measuring instruments whose operation is based on dividing (quantizing) the quantity to be measured into small parts and then counting these parts have been used for a long time (for instance, dc potentiometers). Recently, instruments have come into use which quantize and count the small parts automatically in small equal intervals of time. These digital discrete-action instruments can be either electromechanical or electronic. Below we examine the principal methods of designing electronic digital instruments.

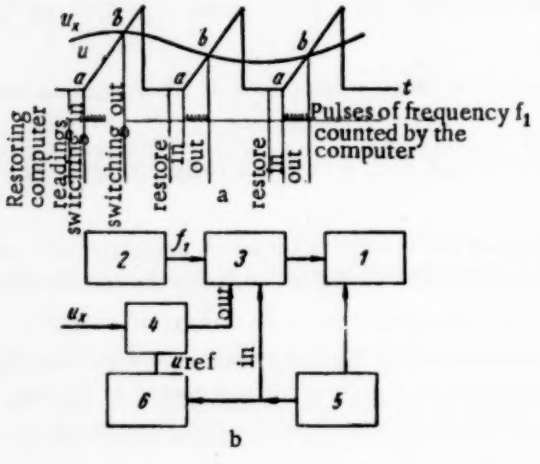


Fig. 1

In recent years electronic digital discrete-action instruments have been used on an increasingly wider scale in various spheres of measurements and automation. The rapid adoption of digital instruments is due to modern large centralized industrial establishments and scientific research organizations requiring not only more precise and higher-speed instruments, but also a more efficient and speedy utilization of the results of the numerous measurements they carry out, especially in studying the dynamics of the object under test.

The prospects of using discrete-action devices in complicated precision measurements are determined both by their speed of operation and clear display of readings, and by the possibility of connecting them directly to computers. The discrete-action instruments provide a much higher accuracy than normal instruments due both to the considerable lowering of the effect of surrounding conditions on measurements (temperature, pressure, humidity, etc.) and to the elimination of the subjective errors due to the observer. This, however, is not the only reason for their popularity. Their popularity is also due to their ability to measure changing values reliably and speedily, provide data on dynamic phenomena, measure periodic quantities, etc.

Industrial digital instruments, in turn, measure the output voltages of many transducers which are connected to the objects under investigation. The instrument itself converts the instantaneous values of the constantly changing measured quantities into their numerical equivalents. The output of the instrument can be connected to a visual display device, a recording device (printer, perforator or tape recorder), a high-speed electronic computer, or a device for automatic control or signalling.

In the devices designed for automatic control or for connection to high-speed electronic computers, the binary system of counting is normally used. The use of the binary system provides a higher operating speed, a minimum number of elements, simplicity, and economy of construction. Devices designed for visual display or recording use the decimal system of counting or the binary coordinated decimal system.

In examining the general characteristics of electronic discrete-action measuring instruments the greatest attention is paid to the unit which serves to convert the measured continuous quantity into a digital equivalent. This unit is also known as the analog-to-digital converter or the coding device.

Fig. 2. a) Pulses with frequency f_1; b) pulses from the 1st null indicator; c) pulses of the auxiliary generator $f_2=(10/9)f_1$; d) pulses at main counter; e) pulses at the auxiliary fractional counter.

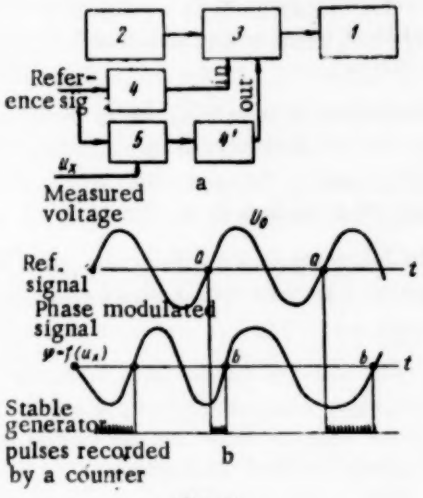


Fig. 3

The most expedient system of classification of analog-to-digital converters seems to be the one based on the principle of operation of the converter unit [1, 2]. This system of classification makes the description and evaluation of instrument characteristics easier. The converters are divided into three groups: a) sequential count converters; b) counting place or weighed converters; c) reading converters.

In comparing the different systems the following properties should be considered: 1) speed of operation; 2) precision; 3) threshold of sensitivity; 4) complexity of the instrument.

Sequential count systems. Systems with sequential count converters, otherwise known as counting coders, are subdivided into three groups: 1) systems with linearly changing voltage; 2) systems with a stepped voltage; and 3) systems with reversible counters.

Systems with a linearly changing voltage [3-5]. In systems with a linearly changing reference voltage, otherwise known as time-coding systems, the measured voltage is converted into a time interval by comparing the measured voltage u_x with a sawtooth reference voltage U_{ref} (Fig. 1a).

At instant a when the linear rise (or drop) of the reference voltage begins, and instant b when the two voltages become equal in the null-indicating circuit 4 (Fig. 1b), two corresponding pulses are produced for controlling counter 1 and the time interval between them is measured. This time interval is measured by a high-speed electronic counter 1, which counts pulses produced by a stable (crystal stabilized) pulse generator 2 of frequency f_1.

TABLE 1

Name of the instrument	Range	Error	Duration of one measurement, sec	Source of information
Electronic digital voltmeter (USSR)	0.2-100 v	0.26%	1	[5]
Delaware Products voltmeter 211 (USA)	0.001-999 v	0.25%	0.025	Rev. Sci.Instr., 1955, No. 10, p. 999
Franklin voltmeter 310 (USA)	0.1-999 v	0.1%	0.05	Electronics, 1955, No. 6, p. 326
Voltmeter VTs-1 (USSR)	0.1-999 v	0.1% ± 0.1 v	0.01	–

Gate 3 is opened by the first of the above-mentioned control pulses a and closed by the second pulse b. In order to control the operation of the whole apparatus either manually or automatically, for single or periodically repeated measurements with the retention of the readings or their automatic restoration to normal, the equipment is supplied with a working cycle control unit 5. This so-called program unit starts at the required instant the reference sawtooth oscillator 6, opens gate 3 which transmits pulses from the stabilized generator 2 to the electronic counter 1, and returns to zero the readings of the counter (restores it to its initial position).

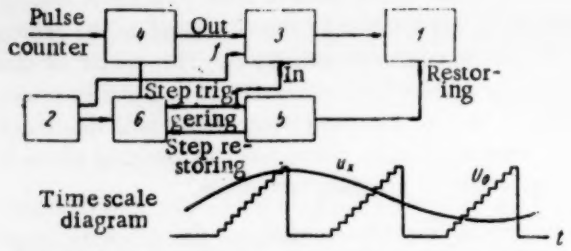


Fig. 4. 1) Pulse counter; 2) position pulse generator; 3) gate; 4) null indicator; 5) operation cycle control unit; 6) step voltage generator.

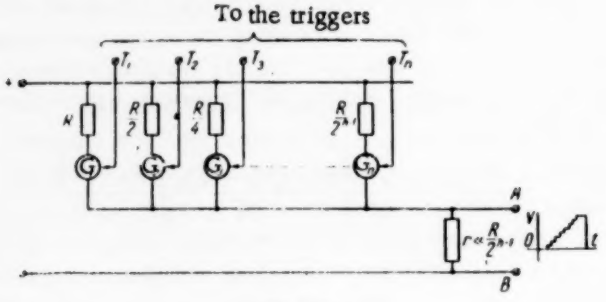


Fig. 5

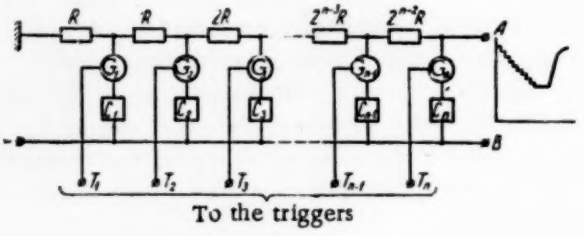


Fig. 6

This measuring system can be supplied with an electrical vernier for greater accuracy of reading. For this purpose (Fig. 2) at the instant the null indicator produces a pulse showing that the instantaneous value of the sawtooth voltage is equal to the measured voltage, another pulse generator is started, whose frequency is a little higher than f_1 (for instance, $f_2 = 10/9\, f_1$). The number of pulses of frequency f_2 required to make them coincide (in time) with those of frequency f_1 is counted. This count taken on a separate counter represents the fractional value of the reading obtained, i.e., the time interval between the null-indicator pulse and the preceding pulse of frequency f_1, analogously to the readings of a slide gage. Figure 2 shows a reading of 0.6.

Sometimes, in order to speed up measurement, the linear reference voltage is discontinued at the instant it is equal to the measured voltage instead of waiting till it reaches its maximum.

The following factors affect to a great extent the accuracy of systems with a linear reference voltage:

a) the shape of the sawtooth oscillator signal. It must be strictly linear and the slope angle of its linear portion must be stable and correspond accurately to the calibration. According to [3] it is possible to attain a deviation from linearity, i.e., a relative difference in the slope angle at the beginning and end of the linear portion of the order of 0.02%

b) the stability of the reference oscillator frequency f_1. The use of a crystal for stabilizing the oscillator reduces the error due to frequency deviations to an insignificant value.

c) The sensitivity threshold and stability of the comparing device(null indicator). The examples of systems with a linear reference voltage show (Table 1) that the sensitivity and stability of existing null indicators attain 1-10 mv.

The speed of operation of these systems is limited mainly by the electronic counter, since the null indicator and the sawtooth oscillator have theoretically the same speed of operation as the counter, but operate in the instrument at a speed 1/100 to 1/1000 of the counter speed. The maximum permissible pulse repetition frequency f_1 at the counter input is normally equal to 0.5-1.0 Mc. By means of special measures it is possible to raise this frequency to about 2-10 Mc.

It is possible to establish the following relation between the maximum conversion frequency and the required accuracy of operation:

$$F_{cv} = F_{ct}\delta$$

where F_{cv} is the frequency of conversion, cps (the repetition frequency of the sawtooth pulses); F_{ct} is the frequency of the counted pulses f_1, cps; δ is the instantaneous voltage relative conversion error due to the finite value of the frequency of counted pulses (error due to the discrete nature of counting).

For instance, when $f_1 = 1$ Mc and $\delta = 0.1\%$ the value of the conversion frequency is $f_{cv} = 10^3$, i.e., a speed of 1000 conversions per second.

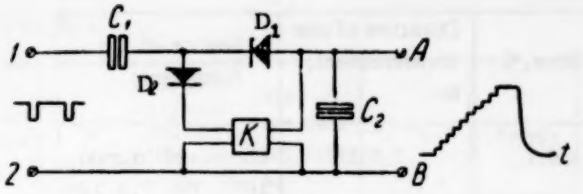


Fig. 7

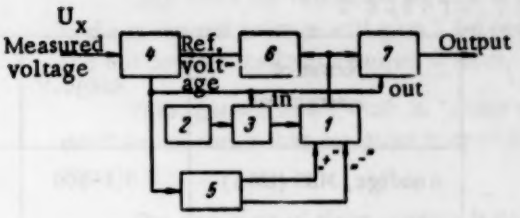


Fig. 8

Table 1 gives a list of certain instruments with linear conversion voltages and cites their main technical characteristics. It will be seen from Table 1 that such systems are made with a minimum conversion error not exceeding 0.1%.

It should be noted that there are versions of similar systems in which the measured voltage is fed to a modulator connected to the counting pulse generator of frequency f_1. In some of the systems frequency phase or pulse-width modulation is used. When frequency modulation is used, the pulses are counted over a fixed time interval. The block schematic of a system with phase difference to time interval conversion is shown in Fig. 3a. The operation of the system is explained by means of a time scale diagrams (Fig. 3b).

The measured signal u_x controls in this system the operation of modulator 5, which consists of a device shifting the phase of a certain reference signal U_0.

The phase displacement is proportional to the instantaneous value of the signal. At the instant the reference signal U_0 passes through zero (instant a) and the phase-modulated signal U'_0 passes through zero (instant b), the null-indicating devices 4 and 4' produce signals for opening and closing gate 3, which controls the operation of the pulse counter.

The electronic counter 1 counts the pulses of the stable pulse generator 2.

A system with a stepped voltage [6]. In such a system, which is a modification of the preceding one, digital conversion is attained by comparing the measured voltage with a number of consecutively rising (or falling) reference voltage steps.

The rise of the reference voltage is fixed every time at a certain predetermined value (step). This discrete value represents the minimum significant figure in the digital conversion. Instead of counting pulses of a stable generator, the number of steps up to the operation of the comparing device is counted in this system. The block schematic of the step-measuring system is shown in Fig. 4. The operation of this system is similar to the one with the sawtooth voltage (Fig. 1) with the difference that instead of the stable pulse generator, a position pulse generator 2 is used, and instead of the sawtooth, a step voltage generator 6 is used. Thus, the requirement for the linearity of the rising voltage and the frequency stability of counting pulses is eliminated, but there arises the requirement for the equality of the steps, since otherwise there will be an accumulation of dispersion errors between the steps.

There exist three basic method of forming the step reference voltage:

a) by means of sequential connection of different current sources to the same point of a reference load resistor (summation of currents). The values of these currents are ranged according to the binary law. The block schematic of the device is shown in Fig. 5. Here G_i are the gates ($i = 1, 2, 3, \ldots n$), which are controlled by signals from the corresponding trigger units T_i of the binary counter. The output step voltage is formed at terminals A–B.

b) by means of consecutive connection of equal current sources to different points of a reference divider consisting of a series of reference resistors R_i, whose values are ranged according to the binary system (summation of voltages). The block schematic of this device is shown in Fig. 6 (R_i are the reference resistors, C_i - current stabilizers, G_i - gates controlled by the unit trigger T_i). The output voltage which decreases in steps is formed at terminals A–B.

c) by accumulating a charge on capacitor C_2 in determined fixed amounts (Fig. 7). This device works by receiving at its input (terminals 1 and 2) periodic pulses of a certain shape. The polarity of the pulses is coordinated with the conducting direction of the diodes in such a manner that during the portion of a period when the pulse

TABLE 2

Name of instrument	Range, v	Error, %	Duration of one measurement, sec	Source of information
Anodige, NBS (USA)	0.1-100	± 0.1	0.0025	Electrical Journal, 1955, No. 7, p. 134
Discrete measuring device	0-20	+0.3	0.004	–

is received, diode D_1 has a small internal resistance (is conducting) and diode D_2 is inoperative and the capacitors C_1 and C_2 are charged. In the interval between pulses, diode D_1 is inoperative and diode D_2 conducting and discharging capacitor C_1 to a voltage equal to the one on capacitor C_2 by means of unit K (cathode follower). This method of operation provides identical output voltage steps.

The main sources of error in these three systems are the instability and the inaccurate adjustment of certain critical parameters. For the first two systems (a and b) these critical parameters include both the currents which feed the reference resistors and the resistors themselves.

The main reason for the inaccuracies of step generator systems is the difference between the steps.

Let us examine, for example, system b. The deviation of the steps from their set values may be due to the following reasons: instability of currents; inequality of currents; errors in the reference resistors.

The stability of the currents connected to the reference resistors depends both on the correct choice of the stabilizers' operating conditions and on the stability of supply voltages (heater, anode, and auxiliary supplies) due to various factors, such as temperature, time, and humidity.

The inequality of currents depends on the measuring equipment used for adjusting them. The error in the values of the reference resistors depends, in addition to the already mentioned factors, on the material they are made of, their construction, and the technology of their manufacture. The instability errors of the currents and the reference resistors can be checked in a static operation of the equipment. The effect of the various combinations of connected and disconnected current sources on the output voltage of the generator can also be checked in a static condition. Additional distortion of the shape of the generator output voltage curve can be produced in a dynamic condition. These distortions can be observed on an oscilloscope screen in the form of irregularities in the shape of steps, spikes between steps, and distortion of the leading edges. These irregularities are due to stray capacitances and inductances in the circuit, interference and pickup, and insufficient speed of operation of various trigger circuits.

Some concrete examples of systems with step voltages are given in Table 2 from which it will be seen that these instruments have, similarly to the previously examined instruments, a minimum error not better than 0.1% and a speed of operation of the order of 500 measurements per second.

Reversible counter system [7]. A reversible counter system (see block schematic in Fig. 8) differs from the preceding system by being a discrete-action servosystem with static compensation, i.e., it follows constantly the level of the measured signal instead of periodically comparing it dynamically with a sawtooth voltage. This system includes a device 6 (which we shall call for brevity a decoding device) in which the reversible counter's(1) discrete conditions (its readings) are transformed into a discrete electrical voltage. The decoding device 6 is connected in such a manner that the measured voltage is being constantly compared by the null-indicator 4 with the readings of counter 1 converted into voltages. Another additional device of the system is discriminator 5, which determines the sign of the reference voltage (obtained from the decoding device) with respect to the measured voltage. When a difference between the measured and the reference voltage, obtained from the decoding device (the counter "reading") appears, its sign is determined and an instruction signal of "addition" or "subtraction" is sent out to the reversible counter 1. The latter can either add or subtract unit pulses depending on the condition of the appropriate counter unit which indicates the direction of counting. After the direction-of-counting signal has been sent, gate 3 is opened and the reversible counter 1 receives a series of pulses from the pulse generator 2. These pulses are registered by counter 1 until its readings again correspond to the measured voltage.

TABLE 3

u_x = 87.24 v

Binary place	u_x	Sequential components of the ref. voltage	u_{ref} (prevailing voltage)	$u_x - u_{ref}$	Result
1	87.24	64	64	23.24	1
2	87.24	32	96	− 8.76	0
3	87.24	16	80	7.24	1
4	87.24	8	88	− 0.76	0
5	87.24	4	84	3.24	1
6	87.24	2	86	1.24	1
7	87.24	1	87	0.24	1
8	87.24	0.5	87.5	− 0.26	0
9	87.24	0.25	87.25	− 0.01	0
10	87.24	0.125	87.125	0.015	1

Result $(1010111.001)_2 = (87.125)_{10}$

TABLE 4

$u_x^l - u_{ref}$	×2	Result
87.24 - 64 = +23.24	46.48	
46.48 − 64 = − 18.48	92.96	0
97.96 - 64 = +28.96	57.92	1
57.92 − 64 = − 6.08	115.84	0
115.85 − 64 = +51.84	103.68	1
103.68 − 64 = +39.68	79.36	1
79.36 - 64 = +15.36	30.72	1
30.72 − 64 = −33.28	61.44	0
61.44 − 64 = − 2.56	122.88	0
122.88 - 64 = +58.88	117.76	1

TABLE 5

Comparing operation	Difference	Result
87.24−64	+23.24	1
23.24−32	− 8.76	0
− 8.76+16	+ 7.24	1
7.24− 8	− 0.76	0
− 0.76+ 4	+ 3.24	1
3.24− 2	+ 1.24	1
1.24− 1	+ 0.24	1
0.24 - 0.5	- 0.26	0
− 0.26+ 0.25	− 0.01	0
− 0.01+ 0.125	+ 0.114	1

Only when the reference voltage is equal to the measured voltage will gate 7 be opened and the counter readings restored to zero.

Thus, gates 3 and 7 work in "phase opposition" (when one is shut the other is open, and vice versa).

The accuracy of these systems is determined by the same factors as those of the systems previously described. In [7] concrete examples of such systems are described without, however, giving their technical characteristics. The errors of measurement of these systems are of the same order as for the systems previously described. Their speed of operation, however, is 10-100 times faster.

Weighing device systems [8-12] (counting code converters). In these systems the voltage is converted by periodically comparing it with a sequence of reference voltages. This reference voltage sequence consists of the unit sums for each counting place of the chosen counting system.

At each partial comparison the measured input voltage is compared with the sequence sum of the reference voltage components. The prevailing figure consists of the sum of voltages which were connected for the previous partial comparison and the voltage corresponding to the units of the next lowest counting place. In the case of the binary system the values of these fixed components constitute a geometrical progression with a common ratio equal to 1/2. If the input voltage (the measured signal) is larger than the prevailing reference voltage, the latter remains connected and is used in forming subsequent reference voltages. At the same time unity is registered in the corresponding binary place.

If the input voltage is smaller than the prevailing reference voltage, zero is registered in the corresponding binary place and the reference voltage component belonging to the next lower binary place is excluded from the sum of reference voltages.

Let us now give a numerical example of the conversion of a measured voltage (for instance 87.24 v) into a 10 digit binary code with the lowest binary place of $2^{-3} = 0.125$ (Table 3).

The block schematic of such a weighted device is shown in Fig. 9. Unit 1 of this system produces, connects, and disconnects reference voltages. For this purpose unit 1 contains a stabilized rectifier which feeds tapped series-connected reference resistors. The switching of these taps is accomplished by a binary counter included in the unit. The input of this counter is fed with pulses from a cadence generator 2 which sustains the operation rhythm of the system.

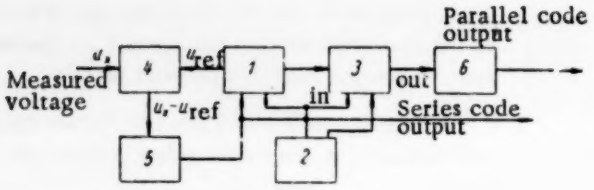


Fig. 9

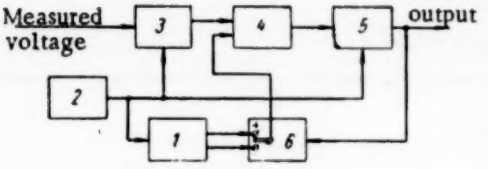


Fig. 10

The counter condition determines the unit 1 output signal, i.e., the reference voltage u_{ref}, which is subtracted in the comparison unit 4 from the measured signal u_x, fed to the input of the system. The difference signal $u_x - u_{ref}$, obtained at the output of the comparison circuit 4, is amplified and fed to sign discriminator 5, which produces the required pulse for registering unity when it receives a positive signal. A negative signal does not produce a pulse. From discriminator 5 the pulse is fed to the unit 1 control circuit where it operates the required component, making the unit add the voltage corresponding to the sequential binary component to the previous reference voltage.

The discriminator output signals represent a series of binary code pulses of the measured signal u_x. In order to obtain the result in the form of a parallel code, a signal is sent at the appropriate time from the cadence generator 2 to gate 3, through which the condition of unit 1 counter is registered. This condition is registered in the output device 6.

In another version of this system the reference voltage remains constant during the entire measurement, but the voltage with which it is being compared changes. First u_{ref} is subtracted from the measured voltage u_x. The difference thus obtained is doubled and again compared with the reference voltage, i.e., the following arithmetic operation is performed:

$$[2(u_x - u_{ref}) - u_{ref}].$$

According to the sign of this difference either unity (for positive sign) or zero (for negative sign) is recorded. When a negative sign is registered, the previous positive difference is doubled instead of the obtained negative difference. In order to illustrate this, let us take the previous numerical example (Table 4): $u_x = 87.24$ v and $u_{ref} = 64$ v.

The result obtained is the same as before — 1010111.001.

These systems can work with a binary code or a binary coded decimal system or other coding systems. Reference voltages can be obtained by rapidly changing the ratio of a potential divider fed from a stabilized supply or by rapidly connecting stable sources of current to the reference resistor.

In the third version of this system the measured voltage is not supplied constantly to the comparing device, but, in order to reduce the loading of the measured circuit, a voltage sample is obtained from it for charging a storage capacitor, which is then discharged consecutively by fixed voltage steps. If, at a certain stage of discharging, the voltage remaining across the capacitor is smaller than the voltage by which the capacitor has to be discharged in the following step, the capacitor is recharged up to a voltage equal to the difference between the remaining voltage and the voltage by which it has to be discharged. The sign of the remaining voltage after each discharge provides a measure of the unknown voltage. Thus, the effect of the unknown voltage variations during measurement on the results is eliminated.

In order to illustrate the operation, let us take again the same numerical example $u_x = 87.24$ v (Table 5).

The block schematic of the weighted device with a storage capacitor is shown in Fig. 10. Unit 1 produces periodically reference voltage pulses of both polarities by which the storage capacitor has to be discharged during sequential comparison tests. The cadence pulse generator 2 controls the rhythm of the operation. The sampling switch 3 periodically obtains samples of the unknown voltage from the measured circuit and charges the storage capacitor 4. The sign discriminator 5 determines the polarity of the voltage across capacitor 4 and a controlling pulse is sent out accordingly by the feedback switch 6, which selects from generator 1 a voltage of the corresponding polarity for capacitor 4. The sign discriminator 5 simultaneously produces output pulses for registering the results.

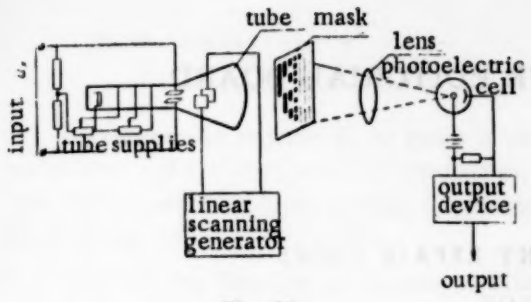


Fig. 11

The accuracy of the weighted systems depends, in the main, on the same factors as those affecting the step voltage systems. Theoretically they can work with the same degree of accuracy as the step voltage system, since the critical factors affecting their accuracy are the precision of the reference voltages and accuracy of the arithmetical and calculating operations.

The speed of operation of these systems is higher than those of the preceding group and according to the available information, attains 50 to $100 \cdot 10^3$ measurements per second.

Systems with coding cathode-ray tubes [13] (reading converters). In systems with coding cathode-ray tubes, otherwise known as reading converters or space coders, the measured voltage is converted into linear vertical displacement of the oscilloscope beam (see Fig. 11). The cathode-ray tube is provided with horizontal scanning. The voltage which is being converted is fed to the vertical deflecting plates of the tube, thus displacing the scanning line vertically by an amount corresponding to the measured voltage. An opaque mask with holes is placed in front of the oscilloscope screen. The holes are located according to the coding required.

In its horizontal movement the beam traverses the coding mask. The sensitive photoelectric cells placed behind the mask register the resulting digital code of the converted voltage.

There exist various versions of this system using different special codes (for instance, Gray's code) or a series of photoelectric cells for obtaining results in the form of a parallel code. All these systems will not be considered here, since, although they provide a high operating speed (of the order of 10^7 conversions per second), they cannot be used for precision measurements, mainly because a high accuracy of deflecting systems cannot be achieved.

One of the basic factors which reduce the accuracy of all the digital measuring systems is the instability (drift) in their components and units. There are various methods of reducing the drift, from simple ageing of the components (resistors, capacitors, tubes, etc.) to the use of thermostats or feedback circuits. For precision measurements, the method consisting of a systematic measurement of reference voltages and an automatic correction of results is of interest, since it provides accurate results, although it complicates the system to a certain extent. This method can be considered as the first step in the direction of automatic correction of the instrument operation.

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MATERIAL RECEIVED BY THE EDITORIAL BOARD

WORKING EXPERIENCE OF WEIGHING-EQUIPMENT REPAIR SHOPS ATTACHED TO THE CHERNIGOV REGION TRACTOR REPAIR STATIONS

M. A. Svirlov

On the suggestion of the Chernigov State Inspection Laboratory of Measuring Equipment the Regional Soviet Executive Committee decided in May, 1959, to organize weighing-equipment repair shops attached to the Semenov, Shchersk, Kozel'sk, Srybnyansk, and Baturinsk Tractor Repair Stations. According to this decision the Tractor Repair Stations selected experienced mechanics with secondary or 7-year education for a three months' training course in the weighing-equipment repair shop of the Chernigov ironware factory.

During the first month (three days a week) the trainees attended a theoretical course, taken by members of the State Inspection Laboratory, in which they were acquainted with the rules and instructions of the Committee and the basic principles of weighing and weighing-equipment repairs; the rest of the time they worked with the weighing equipment repair crew.

All the trainees successfully acquired the skill of repairing ordinary table and dial scales, as well as unequal-arm portable and stationary scales, and became acquainted with the installation of cart and motor-truck weighbridges.

Subsequent work of the trained mechanics showed that the Technical Repair Stations can service the collective farms better than the hardware factory. Thus in the Chernigov region some 200 mechanisms of motor-truck weighbridges were not in use, whereas at present they are being installed. The factory would not accept scales which required welding or woodwork repairs, whereas the Tractor Repair Stations carry out any, including the most complicated repairs.

The collective farms willingly conclude agreements with the Tractor Repair Stations for the repair of scales and, especially, for the installation of motor-truck weighbridges which were lying idle in their stores for several years.

The repairs of scales at the Stations are hindered by the difficulty in supplying the repair shops with standard instruments. Only five of the stations have received for temporary use standard scales and weights; the stations should be able to acquire these instruments in required quantities.

The experience of the work of the Chernigov region Tractor Repair Stations has shown that the carrying out of the weighing-equipment repairs in the stations improved the state of weighing equipment in the collective farms of the region.

FACTORY DESCRIPTION OF INSTRUMENTS

N. N. Kalashnikov

Establishments engaged in the repair of control and measuring instruments often require information on the components and the construction of instruments. Repair mechanics are interested in the type of bearings and cores used, the diameter and brand of wire, the values of the muliplier resistors, resistance of the coils, the torque of spiral springs, etc.

The existing literature on instruments lacks this information. Descriptions attached to the instruments do not exist in the factory.

The lack of this information often leads to improvisation in the repairs of instruments and increases the time taken up by repairs, for instance, in order to repair a burnt-out winding, it is necessary to unwind the old one, counting the turns, and then attempt to determine the type and diameter of the wire, etc.

The instrument-making plants should include in all their descriptions of instruments all the information required by the instrument-repair workers, similar to the procedure established by many of the plants making radio receivers.

Editorial Note. N. N. Kalashnikov's proposal deserves attention and should be followed by the instrument-making plants.

The descriptions attached to newly made instruments should include a full specification of details similar to the specifications attached to radio-electronic instruments.

NOTES ON AMENDMENT NO. 1 TO INSTRUCTIONS 220-55 ON CHECKING HETERODYNE FREQUENCY-METERS TYPE GCh-1M

V. Ya. Volodarskii

The technique proposed by the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements (VNIIFTRI) for checking type GCh-1M heterodyne frequency-meters, without using the VECh "Avangard" equipment, contains certain errors.

Firstly, the checking of the frequency stability of the measuring oscillator, proposed in section I, is incomplete since, according to the suggested method, only the stability with time is checked, which is obviously insufficient for evaluating the stability of the oscillator. Its stability should also be checked with changed measuring conditions when the set is switched from "calibrate" to "measure." A qualitative evaluation of the instability should be made by means of an additional instrument GCh-1 (GCh-1M) or VVT-D used for comparing the frequency of the oscillator in the two working positions.

Secondly, the proposed checking of the measuring oscillator (section III) is incorrect, since it contradicts the "Description and instructions for the use of set GCh-1M" according to which, before checking, the right-hand vernier scale should be set to the calibration value of a frequency multiple of 2 Mc (with a corresponding setting of the left-hand vernier), and then zero beats with a harmonic of the 2 Mc calibrator should be attained by slightly varying the oscillator frequency with the left-hand vernier.

It follows from the above that the evaluation of the oscillator error proposed in amendment No. 1 by measuring the difference between the calibration frequency and that of the 2 Mc calibrator is incorrect.

The measuring instrument should be checked in the following manner:

Set the left-hand vernier scale to a frequency multiple of 10 Mc by beating the oscillator with a harmonic of a 10 Mc crystal calibrator.

Set the right-hand vernier to the calibration of a frequency multiple of 2 Mc, connect the multivibrator (2 Mc), and zero beat the oscillator with a harmonic of the 2 Mc calibrator by means of the left-hand vernier.

Raise the oscillator frequency by 1 Mc by the right-hand vernier (by means of zero beats, which will be weaker at frequency multiples of 1 Mc than those multiples of 2 Mc), then take the readings of the cylindrical and disk scales and determine the oscillator calibration error at a point of (250 + 2n + 1) Mc, where n is an integer.

In order to avoid the effect of backlash, the error should be determined at a point of 250 + 2(n + 1) Mc with the oscillator calibration at a point of (250 + 2n) Mc.

These errors in Amendment No. 1 require its redrafting. When a new appendix to instruction 220-55 is issued (or when the instruction is redrafted) it should be remembered that there exist simple and precise methods of checking the GCh-1M heterodyne frequency-meters without the use of complicated or expensive equipment (for instance, by means of the calibration oscillator KG-V).

USEFUL COURSES

P. N. Stebelev

In connection with the changeover to new methods of State Inspection of measures and measuring equipment, the training of personnel becomes especially important. In order to raise the qualifications of the personnel of area laboratories, departmental inspection agencies, and instrument repair establishments of the basic Scientific and Technical Agency Organizations, the Industrial Instrument Department of the Lugansk Stage Inspection Laboratory organized three-month courses with 160-hour study programs. These part-time courses were attended by 34 people from 17 establishments.

The course included such subjects as measurement techniques for linear and angle measurements (60 hr), electrical measurements (50 hr), practical laboratory work in checking electrical instruments (60 hr) and linear and angle measuring instruments (80 hr), repair of electrical instruments (30 hr), and a course on elementary metrology and supervision of measures and measuring instruments (20 hr).

The lecturers at the course consisted mainly of members of the Lugansk State Inspection Laboratory and the most qualified personnel of the factory laboratories and the instrument repair plant "Vestochmash."

On completion of their studies, the students raised their qualifications in the sphere of instrument inspection, became acquainted with the basic regulations regarding measures and measuring instruments, and acquired the necessary knowledge for working under the new conditions of state inspection, involving the introduction of new measurement equipment in the plants.

The expediency of such courses is determined by the need of establishments for measuring equipment specialists.

At present, the Lugansk State Inspection Laboratory in conjunction with the basic organizations of the Industrial Instrument Department of the Scientific and Technical Agencies is developing a program for similar courses in mechanical and thermotechnical measurements.

INSTALLING LABORATORIES IN TWO-AXLE TRAILERS

A. F. Bugakov

In order to carry out the work of the State Inspection Laboratories in rural districts, mobile laboratories installed in two-axle trailers of motor trucks should be used. Thus, the inspection of instruments on the spot will be extended and the utilization of motor trucks improved.

INFORMATION

INTERNATIONAL SYMPOSIUM ON THE METROLOGY OF RADIOACTIVE ISOTOPES

K. K. Aglintsev and V. V. Bochkarev

A symposium on the metrology of radioactive isotopes, organized by the International Atomic Energy Agency, was held in Vienna on October 14-16, 1959. Some 100 scientists from 27 countries and about 20 representatives of various organizations (CERN, Euratom, IAEA, and others) participated in the work of the symposium.

At the symposium, 37 papers were read and discussed, including 7 papers reviewing the official methods of measuring radioactive isotopes adopted in several states, one paper on international comparisons of standard preparations, and 21 papers on original research in the development of methods and techniques of measuring radioactivity of preparations. The remaining 8 papers dealt with the application of metrology in various spheres for solving physical and technical problems.

Papers reviewing the state of the art in their respective countries were presented by the USSR, Canada, France, USA, Britain, FGR, and Sweden. In Canada, there are two establishments responsible for measuring radioactivity: the National Research Council in Ottawa and the Canadian "Atomic Energy" Company. The laboratories of these establishments use for radioactivity calibration measurements beta particle counters and beta-gamma coincidence counters working on the basis of a 4-π geometry (4-π beta and 4-π beta-gamma counters). The radioactivity of gases is measured by means of gas counters.

In France, calibration measurements are carried out by three laboratories: the Radium Institute, the Nuclear Center in Saclay, and the newly established National Laboratory of the "Arts and Crafts Conservatory." The following calibrating equipment is used: 4-π beta counters, working under geiger and proportional conditions, and x-ray meters which determine the radioactivity of gamma-radiators by the dose they produce. Relative measurements of radioactivity are carried out by means of beta and gamma ionization chambers. In addition to measuring radioactivity, the production of standard radiators is also carried out in France. During 9 months of 1959, 300 such radiators were produced.

In the FGR, absolute measurements of radioactivity are carried out in the Physikalische Technische Bundesanstalt, in Brunswick, where they use 4-π beta and 4-π beta-gamma counters and 4-π gamma ionization chambers. Standard sources of long-life isotopes are being produced in the FGR, including Co^{60} and $Sr^{90} + Y^{90}$. The production of certain short-life isotopes is planned for 1960 (P^{32}, Au^{198}, and Na^{24}).

In Britain there are three laboratories which supply reference sources: the National Physical Laboratory, the Research Establishment of Harwell, and the Radiochemical Center. In 1958, the NPL provided 142 sources, including 30 for international comparisons. The Harwell laboratory supplied some 500 sources of 60 different isotopes, and the Radiochemical laboratory during 9 months of 1959 supplied some 800 sources, including 100 alpha, 200 gamma, 100 liquid beta, and 400 solid beta sources.

The British laboratories possess 4-π beta and 4-π beta-gamma counters. The beta-radiators with a low beta spectrum energy (tritium, C^{14}) are measured by means of liquid scintillators and gas counters.

Absolute measurements are being organized in Sweden, in connection with the production of isotopes by the Swedish reactor in 1960. The laboratory is working with 4-π beta proportional counters and 2-π counters.

The calibration of radioactive preparations in the USA is carried out by the National Bureau of Standards. Preparations of naturally radioactive substances which emit alpha particles are measured by means of differential

microcalorimeters. Open radium preparations are measured against radon by means of 2-π alpha proportional counters. Calibration of artificially radioactive substances with a maximum beta-spectrum energy higher than 300 kev is made on 4-π beta counters used in proportional or geiger condition. Beta radiators with a lower energy are calibrated by means of gas counters or calorimeters. Beta-gamma radiators are calibrated by counting coincidences. Isotopes which disintegrate by electron capture are calibrated by means of counting x-gamma coincidences. The NBS also uses 4-π scintillation counters and 4-π counters with liquid scintillators. (Relative measurements of tritium and C^{14} are made by means of 2-π beta and 4-π gamma ionization chambers.)

The NBS produces standard sources of various radioactive isotopes: Ra(D + E), U, Co^{60}, P^{32}, K^{42}, T^{131}, Ta^{182}, Au^{198}, Sr^{90} + Y^{90}, Te^{204}, Na^{22}, C^{14}, H^{3}, Cs^{137}, S^{35}, Kr^{85}, Hg^{203}, and Ra^{226}.

The paper read by the USSR delegation (K. K. Aglintsev, V. V. Bochkarev, V. M. Grablevskii, and F. M. Karavaev) on the method of measuring radioactivity in the USSR, in addition to describing the existing equipment, also dealt with certain theoretical considerations on the subject of measurements. It was pointed out that practical application of isotopes required a very close connection between the measurements of radioactivity and dosage. The paper dealt not only with standard sources but also with reference sources for checking radiometric and dosimetric equipment.

The symposium paid considerable attention to the international comparison of standard radioactive preparations. It was stated that several countries are taking part in such comparisons (USA, France, FGR, Britain, GDR, Chile, Sweden, the Union of South Africa, and Japan), and that the measurements of the same preparation made in different countries are in good agreement with each other. Usually the difference in measurements does not exceed 2-3% and only seldom does it attain 5-7%.

In the original research on radioactive measurements the greatest number of papers dealt with the 4-π counting method. These papers described the technology of making the counters and their components, the preparation of samples, including the technique of producing films, and analyzed in detail various corrections of the measurement results.

Several papers, including the one of the Soviet delegation (V. V. Bochkarev and V. A. Bazhenov) dealt with absolute measurement methods of the radioactivity of beta-active gases by means of internal filling counters. The design of counters and the effect of various factors on the measurement accuracy were examined. V. V. Bochkarev and V. A. Bazhenov described in their paper the application of this method for measuring the radioactivity of volatile liquids by means of their vapors.

The paper on a speedy method of working out results of mass measurements of preparations by means of special computers, thus providing a considerable economy in time and personnel, aroused great interest. Several papers dealt with measurements of preparations with very weak radioactivity. In order to decrease the background radiations, it is proposed to use water screening (2-2.5 m thick) and anticoincidence circuits. Great difficulties are caused by radioactive impurities in chemical reagents and in materials used for the manufacture of the measuring equipment.

In addition to the above-mentioned questions, the symposium discussed several papers on the technique of alpha counting, the measurement of the radioactivity of isotopes which disintegrate by electron capture, the technique of scintillation counting, etc.

THE THIRD INTERNATIONAL CONFERENCE ON "MEASUREMENT OF HARDNESS IN THEORY AND PRACTICE"

V. V. Varnello and N. P. Slavina

The third International Conference on "Measurements of Hardness in Theory and Practice," organized by the Union of German Engineers in conjunction with the State Administration for Testing Materials of North Rhine-Westphalia, was held in Dortmund (FGR) September 23-25, 1959.

Some 300 delegates from Britain, Austria, Hungary, Italy, GDR, Poland, USSR, USA, France, FGR, Sweden, and Japan and representatives of industry in the FGR took part in the conference. At the three plenary sessions of the Conference 27 papers were read on various aspects of measuring hardness and microhardness, including the problems of the physical basis of hardness measurements.

The USSR delegates read two papers which were presented by the D. I. Mendeleev Scientific Research Institute and aroused great interest among the delegates.

In the paper entitled "A method adopted in the USSR for testing conical and pyramid-shaped diamond tips" (Candidate of Technical Sciences V. V. Varnello) the testing method was described, and a new method outlined of investigating the shape of the working part of a diamond tip by means of obtaining on a special press lamination diagrams which make it possible to judge the defects in the shape of a tip.

The paper entitled "Reference instruments developed by the VNIIM for measuring hardness by the Rockwell or Vickers methods," read by the USSR delegation (Candidate of Technical Sciences N. P. Slavina) dealt with the new reference instruments, developed by the All-Union Scientific Research Institute of Metrology (VNIIM) and designed for calibrating hardness measures in HR and HV scales. High precision of measurement is provided by automation, the reproducibility with great constancy of the pressing-in process, a high precision measurement of deformations attained by using optical devices with small graduations (0.15 μ for the Rockwell and 0.3 μ for the Vickers method), and by a great rigidity of all the instrument components, which eliminates any elastic strains occurring as the result of measurements.

Metal	Hardness HB, kg-wt/mm^2	y_0 in tension, kg-wt/mm^2
Aluminum	13.0	13.0
Copper	31.0	30.1
Nickel	61.0	59.75
Iron	54.0	53.75

Professor Kapler's paper (FGR) was very interesting from the point of view of showing the relation between hardness and other mechanical properties. In his paper he put forward two problems in measuring hardness:

1) establishing a relationship between the hardness numbers obtained by pressing in tips of various shapes;

2) establishing the relationship between hardness numbers and other plastic characteristics of metals determined from tensile and twisting tests.

The paper provides for certain pure metal constants, which are obtained from tensile and twisting tests, and closely correspond to Brinell hardness numbers (see table).

Akashi (Japan) and Boucle (France) dealt in their papers with the interesting problem of measuring microhardness, for instance, the effect of a load and the speed of its application on the microhardness numbers.

The Central Institute for Supervision of Weights and Measures (Tokyo) presented a paper on a new optical method of measuring microhardness. The maximum effort used for pressing in the tip into the sample under test is 1500 g-wt and the tip used consists of a diamond Vickers pyramid; the time of pressing and loading should not exceed 100 sec.

The diagrammatic recording apparatus provides a greatly enlarged curve of the impression in terms of depth of impression against load. The effort is applied to the tip by means of weights "floating" in water when the water is let out.

In his paper on standardization of hardness measurements with small loads, Prof. Boucle noted that the largest dispersion of microhardness values occurs when it is determined at loads below 10 g-wt. At loads between 1 and 3 g-wt the dispersion often exceeds 100%, at loads between 100 and 200 g-wt it is 10%, and above 3000 g-wt it is only 3%.

The microhardness of alloys depends substantially on the load at which it is measured. Thus, the microhardness of an alloy determined at loads of 5, 10, and 20 g-wt changes in the following manner: $H_{5\mu} = 260$, $H_{10\mu} = 232$, and $H_{20\mu} = 185$.

In conclusion, it was pointed out that the measurement of microhardness was a very complicated and pressing problem and that the standardization of hardness measurements at small loads is an urgent task for the institutes dealing with standardization.

The exceptional interest taken in the work of the conference by the delegates of all the countries should be noted. The growing interest in the work of the conference is due to the pressing nature of the questions discussed and the concern with many theoretical and practical problems in the measurement of hardness and microhardness.

CONFERENCE FOR THE EXCHANGE OF EXPERIENCE IN INTRODUCING NEW MEASUREMENT TECHNIQUES

D. M. Sizov

A regional conference of the heads of industrial laboratories called for the exchange of experiences in introducing new measurement techniques, and organized by the Zaporozh'e State Inspection Laboratory in conjunction with the Central Bureau of Technical Information of the Zaporozh'e Council of National Economy, was held in Zaporozh'e in August, 1959. The conference was attended by 64 representatives of 32 industrial establishments of the Zaporozh'e Council of National Economy.

Two reports were made at the conference. In the first it was noted that the work of the Central Test Laboratories in introducing new measurement techniques at the plants has two aspects:

1) the introduction of new techniques and modernization of the equipment possessed by the laboratories;

2) the introduction of better inspection methods in the production of components.

The Central Test Laboratory carried out the following work:

1) it produced a new spindle for a horizontal telescope caliper thus increasing its range of measurement;

2) it modified a telescope height gage for three-dimensional measurements by changing the construction of its table;

3) it combined an optical dividing head with an optical distance gage for measuring details with regularly placed spline teeth along a circumference. This device provides an accurate measurement of the angular position of teeth components;

4) it produced a sine-measuring table with a double slope for checking flat surfaces at various angles;

5) it constructed an instrument for checking guiding surfaces in mills which measures both the conditions of the surfaces and their parallelism.

The introduction of better inspection methods in the production of components raised labor productivity and decreased scrap .

A large number of measuring instruments which check the dimensions of details in production have been installed on grinding machines at the last stage of manufacture. Thus the number of rejects was considerably decreased.

Inspection mechanization of finished components was achieved by providing production indicators and electrical contact instruments which measure simultaneously several dimensions of the commodity. This measure greatly raised the productivity of the inspector's work and made it much easier.

Pneumatic methods of checking small details have been widely adopted at the plants and are carried out, for instance, by means of pneumatic distance gages.

At present, transducers for the pneumatic equipment are being developed.

The representative of the "Zaporozhstal'" plant reported that the introduction of the new measurement techniques is carried out according to a plan drawn up in conjunction with the Zaporozh'e State Inspection Laboratory.

The "Zaporozhstal'" Measuring Instrument Shop has already implemented 70% of the planned measures. Of these measures the following deserve attention.

The electrical instruments which indicated the speed of the sintering shop conveyor belt were replaced by electronic instruments which record the speed in meters per minute. The sintering process is now checked by the recorded conveyor speed. Electrical galvanometers have been replaced by electronic ones. An automatic dust meter has been installed which registers dust concentration in the discharge gases of the sintering machine, thus protecting the fan blades from wear.

One of the blast furnaces is completely equipped with miniature electronic instruments.

In the slab mill the SP potentiometers have been replaced by electronic ones. The conversion of the potentiometers was carried out by the measuring and control instrument shop.

At the oxygen station, mercury flow-meters have been replaced by electronic ones.

In several shops new instruments have been introduced which provide good service, for instance, a photoelectric instrument for automatic measurement of the width of a hot-rolled metal strip reduces scrap with respect to the strip width by 50% and dispenses with manual measurements.

Noncontact isotopic thickness gages have been installed in the sheet metal shop, reducing scrap by 30% and making the work in the shop easier.

In the electrolytic department, isotopic gages for checking the tin coating thickness on sheets provide considerable economy in the use of tin.

In order to extend and intensify the introduction of new measuring equipment, the conference decided to establish under the auspices of the Central Bureau of Technical Information of the Zaporozh'e Council of National Economy a permanent seminar for measurement techniques.

The constitution of the seminar was approved and its members elected from nominations presented by the State Inspection Laboratories, the Council of National Economy, and heads of the factory laboratories.

A report by the head of the Zaporozh'e State Inspection Laboratory on the introduction by the Committee of Standards, Measures, and Measuring Instruments of new rules 12-58 for January 1, 1960 was presented to the Conference.

Many representatives of industrial establishments took part in the discussion.

The conference decided to accelerate the introduction of new measurement techniques and the exchange of experiences.

THE COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

GOST 3637-59. Spirit gages made of glass. Replacing GOST 3637-47.

GOST 3883-59. Pitch gage for gear wheels. Replacing GOST 3883-50.

GOST 4446-59. Tangential tooth gages. Replacing GOST 4446-48.

GOST 6915-59. Indicating instruments for measuring arterial pressure. Technical requirements. Replacing GOST 6915-54.

GOST 8335-59. Optical pyrometers. Replacing GOST 8335-57

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

(Registered in September – October, 1959)

A device for determining the magnetic characteristics of thin electrical steel sheets. Trade mark U578 of the Kiev Sovnarkhoz. State register No. 1275-59.

Through current transformers with moulded insulation. Trade mark TPL-10 of the Sverdlovsk Sovnarkhoz. State register No. 1276-59.

Instrument for measuring the interelectrode capacitance of radio tubes. Trade mark "PIMEL" of the Belorussian Sovnarkhoz. State register No. 1277-59.

Saturated double standard cells, II class, of the L'vov Sovnarkhoz. State register No. 1278-59.

Equipment for measuring large direct currents. Trade mark I505 of the Kiev Sovnarkhoz. State register No. 1279-59.

Rectifying equipment for remote measuring of ac current on demand, consisting of a correcting transformer KT-1, a rectifying device VU-1 b, and a receiver TM-A2 or PMDG, of the Leningrad Sovnarkhoz. State register No. 1280-59.

An induction-rectification apparatus for remote measurement of steam, consisting of a manometer with an induction transducer type MPI-1, a voltage stabilizer SN-1 or SNÉ-120-0.1, a rectifier VU-1a and a receiver type TM-A2 or PMDG-1, of the Leningrad Sovnarkhoz. State register No. 1281-59.

A rectifying apparatus for remote measuring of alternating currents, consisting of a current rectifier VPT-1a and a receiver TM-A2 or PMDG-1, of the Leningrad Sovnarkhoz. State register No. 1282-59.

Rectifying equipment for remote measuring of ac voltage, consisting of a rectifier VPN-1a and a receiver TM-A2 or PMDG-1, of the Leningrad Sovnarkhoz. State register No. 1283-59.

Induction-rectification equipment for remote measurement of three-phase power, consisting of a wattmeter converter VAPI-2, a receiver TM-A2 or PMDG, a rectifier VU-1a, and a voltage stabilizer SN-1, of the Leningrad Sovnarkhoz. State register No. 1284-59.

Medical x-ray meter for measuring doses of x- and gamma-rays. Trade mark PM-1M, of the Belorussian Sovnarkhoz. State register No. 1285-59.

Portable multirange recording dc microampere-millivoltmeters. Trade mark N-373, of the Krasnodar Sovnarkhoz. State register No. 1286-59.

DC bridge equipment. Trade mark U-303, of the Krasnodar Sovnarkhoz. State register No. 1287-59.

Portable AVO meters. Trade mark PR-5 of the Ministry of Communications of the USSR. State register No. 1288-59.

Portable calibrated shunts. Trade mark R81/5-9, of the Leningrad Sovnarkhoz. State register No. 1289-59.

Attachment to a horizontal telescope caliper, consisting of horizontal pointed journals. Trade mark PP-3, of the Leningrad Sovnarkhoz. State register No. 1290-59.

Automatic saccharimeters. Trade mark SA-2 of the Kiev Sovnarkhoz. State register No. 1291-59.

Secondary miniature indicating pneumatic instrument. Trade mark 1MP-30A, for measuring one quantity, of the Moscow City Sovnarkhoz. State register No. 1292-59.

Secondary miniature indicating pneumatic instrument. Trade mark 2MP-30V, for measuring one quantity and for indicating the set value and pressure on an actuating mechanism, of the Moscow City Sovnarkhoz. State register No. 1293-59.

Secondary recording miniature pneumatic instrument. Trade mark 1RL-29A, for recording one quantity, of the Moscow City Sovnarkhoz. State register No. 1294-59.

Secondary recording miniature pneumatic instrument. Trade mark 2RL-29B, for recording two quantities, of the Moscow City Sovnarkhoz. State register No. 1295-59.

Secondary recording miniature pneumatic instrument. Trade mark 3RL-29V, for recording one quantity and indicating the set value and pressure on an actuating mechanism, of the Moscow City Sovnarkhoz. State register No. 1296-59.

An apparatus with a weighted piston manometer, grade I. Trade mark UPM-6, for checking weighted piston manometers up to 6 kg-wt/cm^2, of the Latvian Sovnarkhoz. State register No. 1297-59.

Capacitance box. Trade mark P513 of the Kiev Sovnarkhoz. State register No. 1298-59.

Mobile platform scales with weights. Trade mark VPG-1(m), of the Khar'kov Sovnarkhoz. Registered together with the previously approved mobile platform scales with weights, trade mark VPG-2(m). State register No. 1205-58.

III. MEASURES AND MEASURING INSTRUMENTS REMOVED FROM THE STATE REGISTER

DC bridges. Trade mark UMV. State register No. 97.

Analytical balances. Trade mark VA-200. State register No. 108.

Automatic scales. Trade mark AUM. State register No. 126.

Resistance box. Trade mark KMS-6. State register No. 179.

Portable, miniature ammeters. Trade mark M65. State register No. 182.

Resistance box. Trade mark KMS-4. State register No. 203.

Portable miniature voltmeters. Trade mark M65. State register No. 217.

Chemical gas analyzer. Trade mark GKh-1. State register No. 223.

Current transformer. Trade mark LTT-1. State register No. 241.

Rack-mounted indicating galvanometer. Trade mark GPS. State register No. 270.

Single-phase electricity meter. Trade mark M. State register No. 324.

Saccharimeter. Trade mark SOK. State register No. 337.

Portable ammeters. Trade mark ÉP-1. State register No. 349.

Portable voltmeters. Trade mark ÉP-1. State register No. 350.

Milliwebermeter. Trade mark M19. State register No. 392.

Semiautomatic gasoline meters. Trade mark BMP. State register No. 434.

Rack-mounted ammeters. Trade mark M4. State register No. 454.

Rack-mounted voltmeters. Trade mark M4. State register No. 455.

Ammeters. Trade mark M45. State register No. 529.

Voltmeters. Trade mark M45. State register No. 530.

Voltammeters. Trade mark M45. State register No. 531.

Resistance box. Trade mark MKMS. State register No. 532.

Automatic potentiometers. Trade mark SP. State register No. 542.

Mutual inductance coils. Trade mark KV-1. State register No. 547.

Megohmmeter. Trade mark MOM-1. State register No. 565.

DC bridges. Trade mark MKMV. State register No. 570.

Voltammeters. Trade mark Ts-312. State register No. 597.

Measuring microscopes. Trade mark IT. State register No. 599.

Capacitance-type electronic frequency meters. Trade mark ICh-5. State register No. 773.

Rack-mounted recording ammeter and voltmeter. Trade mark M323/1. State register No. 777.

Conveyor scales with a dropping rack. Trade mark VLT. State register No. 790.

Gasoline pump type 801. State register No. 801.

Recording ammeter. Trade mark D331. State register No. 804.

Recording voltmeter. Trade mark D332. State register No. 805.

Recording wattmeters. Trade mark D333. State register No. 806.

Automatic magnetic gas analyzers. State register No. 827.

Decimeters. Trade mark PA, registered together with other decimeters under State register No. 829.

Vibration type miniature frequency meters. Trade mark VChM. State register No. 876.

Recording rack-mounted frequency meters. Trade mark N 305. State register No. 913.

Rack-mounted ammeters. Trade mark M340. State register No. 915.

Rack-mounted voltmeters. Trade mark M340. State register No. 916.

Portable miniature millivoltmeters. Trade mark MV-150. State register No. 953.